TABLE 2.14.— Seasonal fish condition comparisons for Dolly Varden char for all years combined and for individually sampled years. Asterisks (*) indicate significant differences in condition.

		Slopes		Intercepts		
Group	N	b(SE)	P-values	$\log_e a$(SE)	P-values	r^2
			All years			
Early	861	3.12 (0.02)		-12.31 (0.09)		0.98
Late	742	3.02 (0.03)		-11.69 (0.15)		0.96
			P = 0.007		P = 0.0001	
	Without outliers		P = 0.0003		P = 0.0001	
			1988			
Early	217	3.11 (0.02)		-12.31 (0.13)		0.99
Late	36	3.28 (0.06)		-13.13 (0.34)		0.99
			P = 0.04		P = 0.0001	
	Without outliers		P = 0.03		P = 0.0001	
			1989			
Early	68	3.06 (0.02)		-11.92 (0.11)		0.99
Late	119	3.08 (0.02)		-11.94 (0.12)		0.99
			P = 0.50		P = 0.0001	*
	Without outliers		P = 0.50		P = 0.0001	*
			1990			
Early	254	3.13 (0.04)		-12.29 (0.21)		0.97
Late	65	3.35 (0.18)		-13.60 (1.01)		0.84
			P = 0.10		P = 0.19	
	Without outliers		P = 0.03		P = 0.99	
			1991			
Early	322	3.12 (0.02)		-12.43 (0.10)		0.99
Late	122	2.83 (0.06)		-10.66 (0.34)		0.95
			P = 0.0001		P = 0.0001	
	Without outliers		P = 0.0001		P = 0.0001	

TABLE 2.15.— Condition comparisons in overwintering Dolly Varden char for the winters of 1988-89, 1989-90, and 1990-91. Asterisks (*) indicate significant differences in condition.

Group	N	Slopes b(SE)	Slopes P-values	Intercepts $\log_e a$(SE)	Intercepts P-values	r^2
			1988 - 1989			
Fall	36	3.28 (0.06)		-13.13 (0.34)		0.99
Spring	68	3.06 (0.02)		-11.92 (0.11)		0.99
			P = 0.003		P = 0.008	
	Without outliers		P = 0.003		P = 0.008	
			1989 - 1990			
Fall	55	3.17 (0.03)		-12.35 (0.18)		0.99
Spring	254	3.13 (0.04)		-12.29 (0.21)		0.97
			P = 0.66		P = 0.0004	*
	Without outliers		P = 0.68		P = 0.0001	*
			1990 - 1991			
Fall	65	3.36 (0.18)		-13.60 (1.01)		0.84
Spring	322	3.12 (0.02)		-11.43 (0.10)		0.99
			P = 0.02		P = 0.03	
	Without outliers		P = 0.0006		P = 0.0001	

the fall of 1988 (Figure 2.40A) compared to the spring of 1989 (Figure 2.40B). We also observed this trend in the fall of 1990 compared to the spring 1991 (Figures 2.40E-F).

Spatial differences.– Comparisons among areas showed significant differences in condition for fish collected in July. When data were pooled over all years, slope estimates were not significantly different ($P = 0.86$) with outliers removed from the analysis (Table 2.16). In contrast, slopes differed significantly ($P = 0.02$) when outliers were included. Intercepts were significantly different in either case, $P = 0.01$ and $P = 0.0001$, respectively. Pairwise comparisons indicated condition did not differ significantly between Beaufort Lagoon and Simpson Cove ($P > 0.05$), but both differed significantly from the Kaktovik/Jago lagoon complex ($P < 0.05$). Plots of the transformed data (Figures 2.41A-C) indicated fewer small fish were represented in the Simpson Cove and Beaufort Lagoon samples. Also, the Beaufort Lagoon July sample lacked fish in the center of the distribution (Figure 2.41C). During 1991, spatial differences in condition were also significant. Pairwise tests grouped Kaktovik/Jago lagoons separately from Simpson Cove, but neither differed from Beaufort Lagoon.

We also observed differences in condition among areas in fish collected after August 27. Slope estimates were similar ($P = 0.26$) while intercepts differed ($P = 0.01$) (Table 2.17). Pairwise comparisons indicated that condition of fish from Beaufort Lagoon differed ($P < 0.05$) from that of those in Kaktovik and Jago lagoons and Simpson Cove. Fish from the latter two areas showed no differences in condition. Plots of transformed data indicated more small and large fish in Kaktovik and Jago lagoons than in the other sampling areas (Figure 2.41D-F). Intercepts estimates indicated that Beaufort Lagoon fish weighed more at a given length than fish of the other two areas. Removal of outliers changed Kaktovik and Jago lagoons and Simpson Cove. Fish from the latter two areas showed no differences in condition. Coefficients of determinations were variable. Removal of outliers changed slope differences from not significant to significant. Only 1991 samples were large enough to analyze within year. Slope differences in other years did not allow statements about condition unless outliers were removed.

Annual differences.– Among-year results indicated differences in fish condition for Dolly Varden char collected in July (Table 2.18). Slopes were not significantly different ($P = 0.56$) when outliers were retained. When outliers were removed slopes differed significantly ($P = 0.0001$). Intercept values remained significantly different in either case ($P = 0.0001$). Pairwise comparisons indicated that condition 1988 and 1991 were similar, but that condition of those years differed from 1989 and 1990. Fish condition from 1989 and 1990 did not differ significantly. Plots of the transformed data indicated that 1988, 1990, and 1991 data lacked measurements from smaller fish, and larger fish were not evenly represented among years (Figure 2.42).

Among-year comparisons for fish collected after August 27 indicated differences in slope ($P = 0.0003$) precluding statements about condition. Values of r^2 varied (Table 2.19). Plots of transformed data showed a greater size range of fish were present in 1989 when compared to other years (Figure

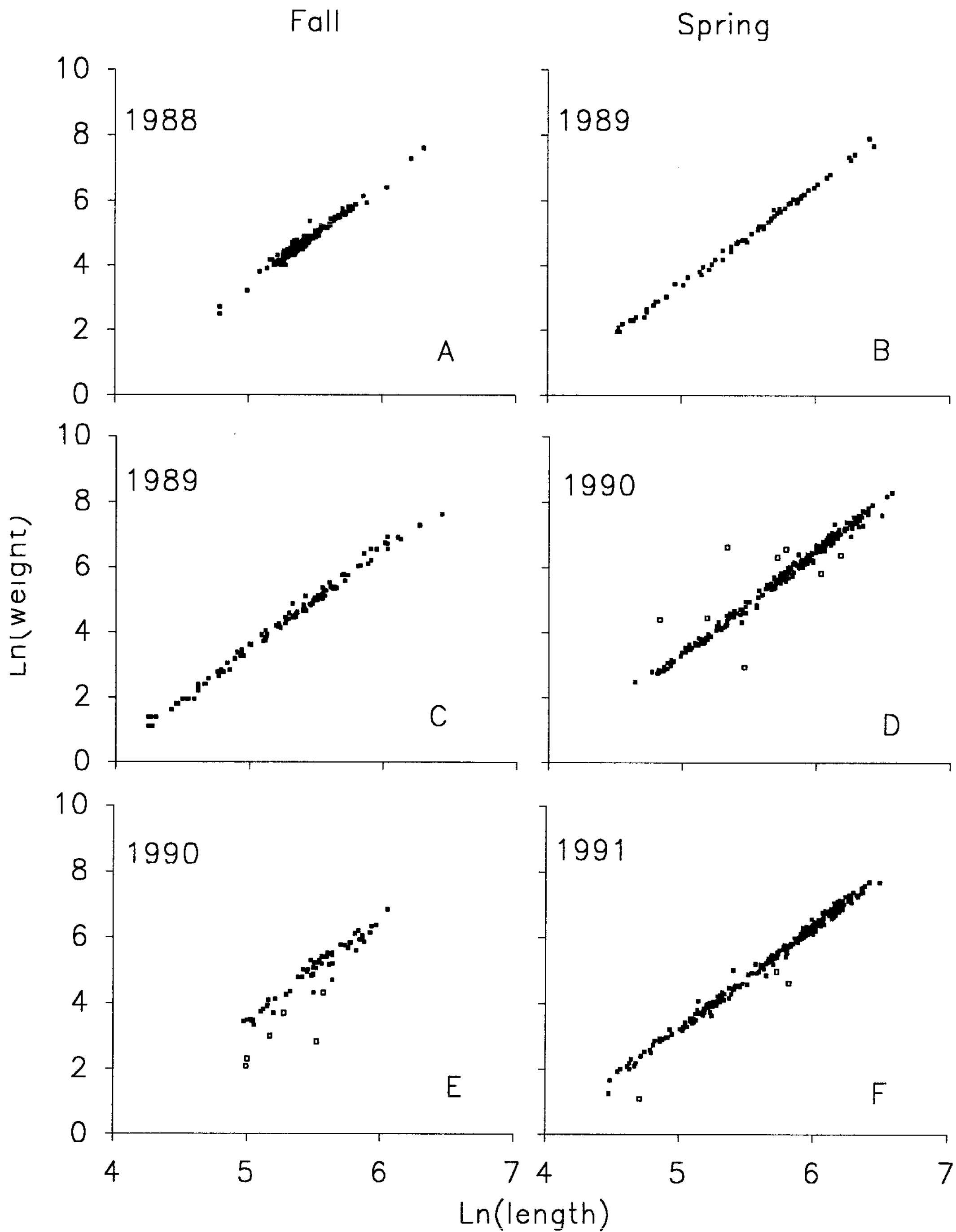

FIGURE 2.40.— Log-transformed weight-length data (□=outliers) used for three comparisons, winter 1988-89, 1989-90, and 1990-91.

TABLE 2.16.— Spatial condition comparisons for Dolly Varden char collected in July for all years combined and sampled years individually. In 1988 sample sizes were too small to analyze separately, but were included in the overall analyses. Asterisks(*) indicate significant differences in condition.

		Slopes		Intercepts			
Group	N	b(SE)	*P*-values	$\log_e a$(SE)	*P*-values	r^2	Pairwise results
			All Years				
Beaufort Lagoon	199	3.14(0.02)		-12.49(0.11)		0.99	A
Kaktovik/Jago	430	3.10(0.01)		-12.22(0.08)		0.99	B
Simpson Cove	221	3.18(0.02)		-12.71(0.14)		0.99	A
			P = 0.02		P = 0.0001		
Without outliers			P = 0.86		P = 0.01	*	
			<u>1990</u>				
Beaufort Lagoon	54	3.21(0.03)		-12.77(0.20)		0.99	
Kaktovik/Jago	98	3.13(0.02)		-12.26(0.12)		0.99	
Simpson Cove	94	3.24(0.03)		-12.97(0.18)		0.99	
			P = 0.80		*P* = 0.35		
Without outliers			*P* = 0.013		*P* = 0.0001		
			<u>1991</u>				
Beaufort Lagoon	145	3.11(0.02)		-12.34(0.10)		0.99	A,B
Kaktovik/Jago	71	3.12(0.02)		-12.38(0.14)		0.99	A
Simpson Cove	103	3.09(0.03)		-12.24(0.19)		0.99	B
			P = 0.13		*P* = 0.36		
Without outliers			*P* = 0.72		*P* = 0.006	*	

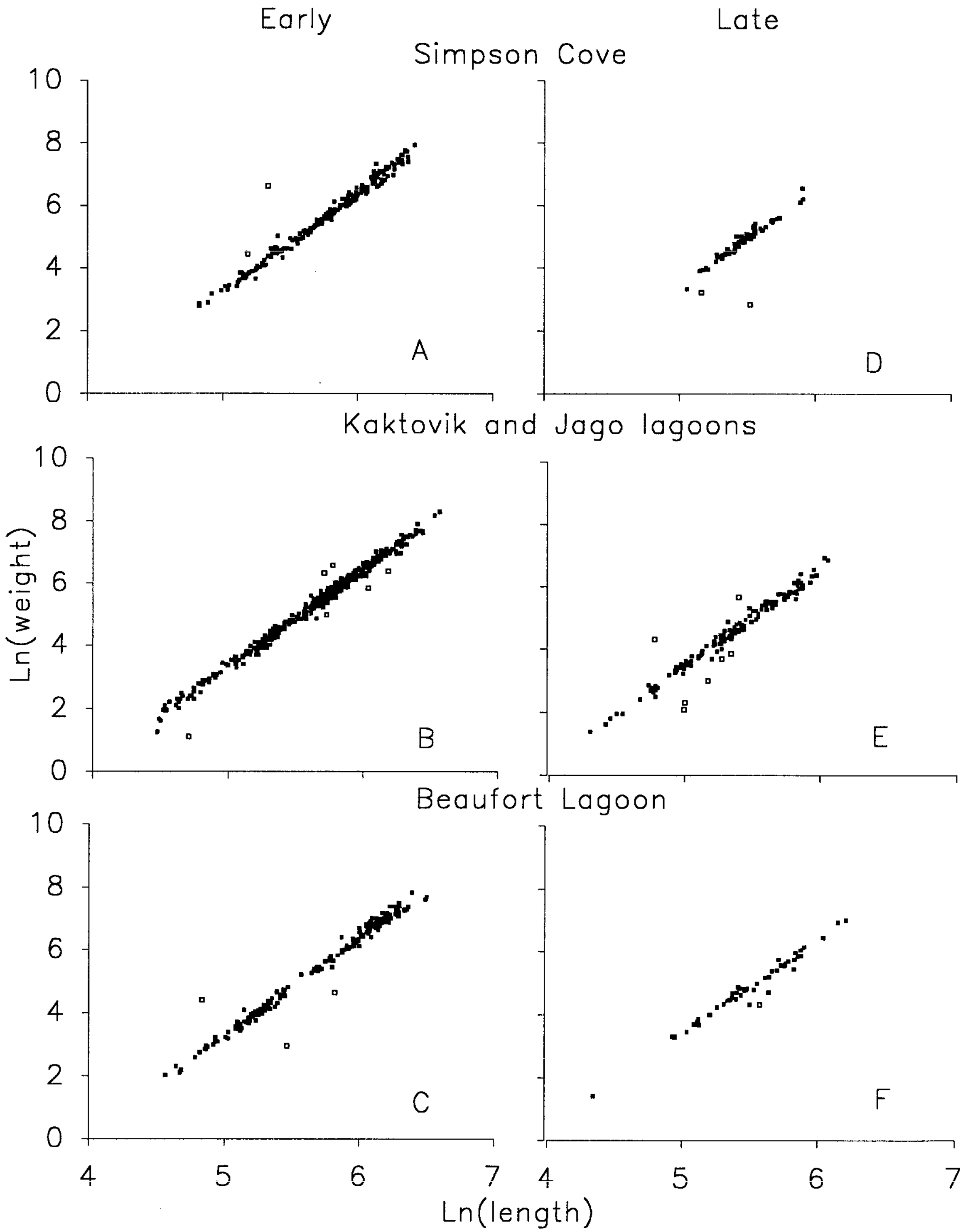

FIGURE 2.41.— Log-transformed weight data (□=outliers) for among-area comparisons, early (July, first column) and late (after August 27, second column) of each year. Plots are compared down the columns.

TABLE 2.17.– Spatial condition comparisons for Dolly Varden char collected after August 27 for all years combined and 1991. Asterisks (*) indicate significant differences in condition.

Group	N	Slopes: b(SE)	Slopes: P-values	Intercepts: $\log_e a$(SE)	Intercepts: P-values	r^2	Pairwise results
All years							
Beaufort Lagoon	51	2.89 (0.08)		-11.07 (0.42)		0.97	A
Kaktovik/Jago Lagoon	148	3.08 (0.06)		-11.97 (0.32)		0.95	B
Simpson Cove	79	3.14 (0.20)		-12.35 (1.11)		0.76	B
			$P = 0.26$		$P = 0.01$	*	
Without outliers			$P = 0.021$		$P = 0.0001$		
1991							
Beaufort Lagoon	43	2.92 (0.05)		-11.19 (0.26)		0.98	A
Kaktovik/Jago Lagoon	46	2.67 (0.14)		-9.75 (0.74)		0.90	B
Simpson Cove	33	3.18 (0.14)		-12.58 (0.77)		0.94	B
			$P = 0.03$		$P = 0.16$		
Without outliers			$P = 0.57$		$P = 0.08$	*	

TABLE 2.18.— Annual condition comparisons for Dolly Varden char collected in July for all sampling areas combined and sampling areas individually. Within individual sampling areas some years were dropped from the analyses if sample sizes were below the minimum (N=32). Asterisks (*) indicate significant differences in condition.

Group	N	Slopes b(SE)	Slopes P-values	Intercepts $\log_e a$(SE)	Intercepts P-values	r^2	Pairwise results
All Areas							
1988	217	3.11 (0.02)		-12.31 (0.13)		0.98	A
1989	68	3.06 (0.02)		-11.91 (0.11)		0.99	B
1990	254	3.13 (0.04)		-12.29 (0.21)		0.96	B
1991	322	2.13 (0.02)		-12.43 (0.10)		0.99	A
			P = 0.56		P = 0.0001	*	
	Without outliers		P = 0.0001		P = 0.0001		
Beaufort Lagoon							
1990	56	3.14 (0.99)		-12.39 (0.53)		0.95	
1991	146	3.11 (0.02)		-12.32 (0.14)		0.99	
			P = 0.57		P = 0.0001	*	
	Without outliers		P = 0.006		P = 0.0001		
Kaktovik and Jago lagoons							
1988	197	3.10 (0.02)		-12.25 (0.14)		0.99	
1989	64	3.06 (0.02)		-11.91 (0.12)		0.99	
1990	102	3.10 (0.04)		-12.08 (0.23)		0.98	
1991	73	3.18 (0.04)		-12.71 (0.23)		0.99	
			P = 0.061		P = 0.0001	*	
	Without outliers		P = 0.006		P = 0.0001		
Simpson Cove							
1990	96	3.15 (0.07)		-12.45 (0.39)		0.96	
1991	103	3.09 (0.03)		-12.24 (0.19)		0.99	
			P = 0.43		P = 0.0001	*	
	Without outliers		P = 0.0001		P = 0.004		

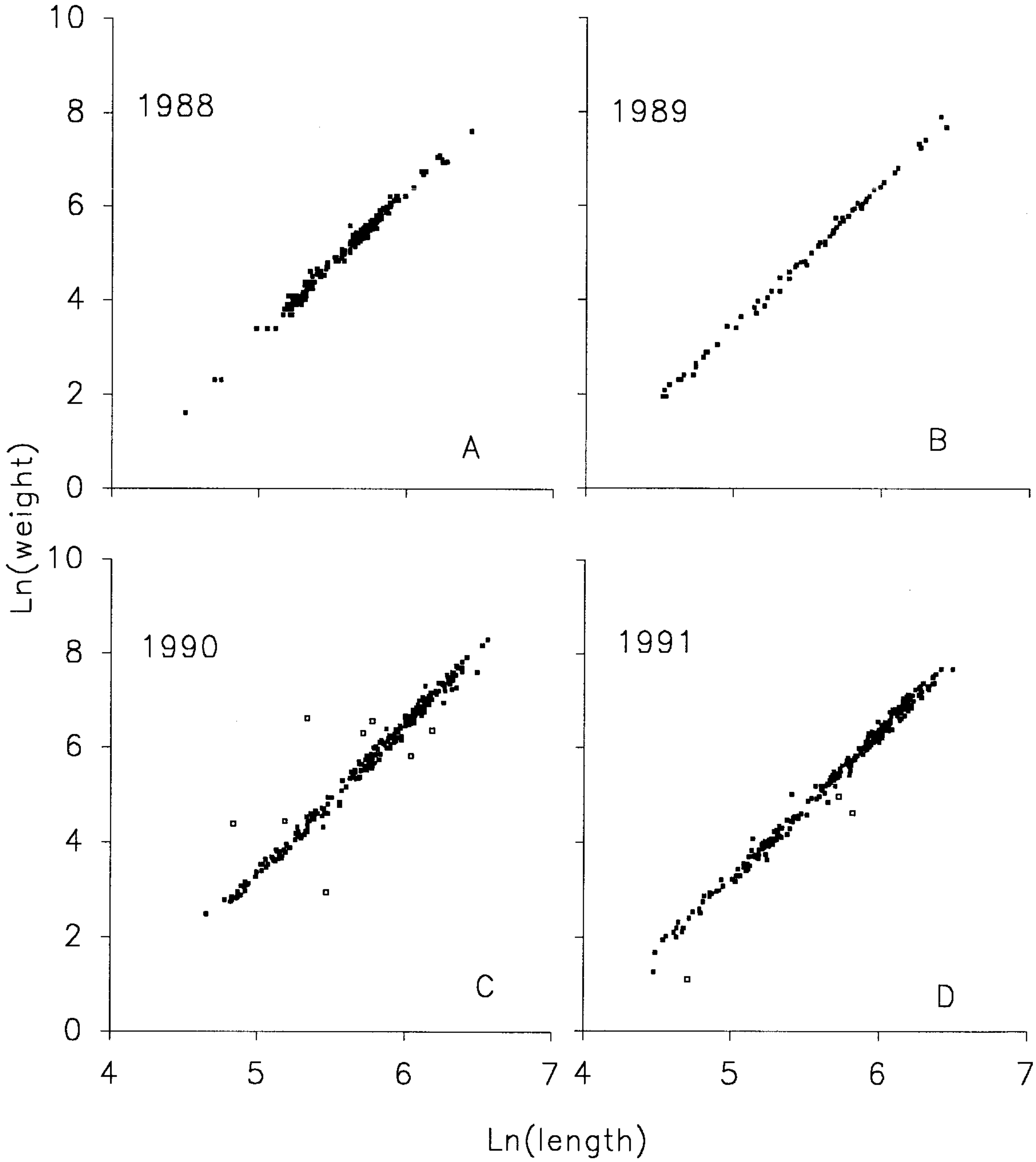

FIGURE 2.42.— Log-transformed Dolly Varden char weight-length data (□=outliers) collected during July in all areas for comparisons among-years.

TABLE 2.19.– Annual condition comparisons for Dolly Varden char collected after August 27 for all sampling areas combined and the Kaktovik/Jago Lagoon separately. Asterisks (*) indicate significant differences in condition.

		Slopes		Intercepts			
Group	N	b(SE)	P-values	$\log_e a$(SE)	P-values	r^2	Pairwise results
			All areas				
1988	36	3.28 (0.06)		-13.13 (0.34)		0.99	
1989	55	3.17 (0.03)		-12.35 (0.18)		0.99	
1990	65	3.36 (0.18)		-13.60 (1.01)		0.84	
1991	122	2.83 (0.06)		-10.66 (0.34)		0.95	
			$P = 0.0003$		$P = 0.0014$		
	Without outliers		$P = 0.0001$		$P = 0.0001$		
			Kaktovik & Jago lagoons				
1989	40	3.22 (0.04)		-12.60 (0.19)		0.99	
1990	46	3.47 (0.15)		-14.17 (0.85)		0.92	
1991	46	2.67 (0.14)		-9.75 (0.74)		0.90	
			$P = 0.0001$		$P = 0.03$		
	Without outliers		$P = 0.0003$		$P = 0.0005$		

2.43). Condition could not be discussed for the data from Kaktovik and Jago lagoons because of differences in slope estimates.

Age and Growth

Dolly Varden char collected during July ranged from 1 to 13 years of age. Age 4 occurred most frequently (25%, N = 70), with age 5 (20%, N = 55) and age 3 (13%, N = 37) as the second and third most frequent ages, respectively. The mean age was 4.8 years (N = 277, SE = 0.1) and the mean length was 314.8 mm FL (N = 277, SE = 7.5). Overlap of length ranges between ages was considerable (Table 2.20). Growth rate indicated by increments between mean lengths at age, was steady until age 8 when mean length reached a plateau (Figure 2.44A).

Significant differences (α = 0.05) in length-at-age among areas occurred for ages 2 and 8 (Table 2.21). However, small sample sizes resulted in tenuous statistical interpretation and such differences may not have been biologically significant. Mean lengths of age 2 char from Simpson Cove were greater than those from Kaktovik and Jago lagoons, but not significantly different from those of Beaufort Lagoon. Mean length of age 2 char from Beaufort Lagoon was not different from that of Kaktovik or Jago lagoons (Table 2.21). Mean lengths of age 8 char in Beaufort Lagoon and Simpson Cove were similar again, but the mean length in Kaktovik Lagoon was similar to that in Simpson Cove, but smaller than that in Beaufort Lagoon (Table 2.21).

Among years, significant differences occurred at ages 2, 4, 6 and 8 (Table 2.22). At those ages, mean lengths from 1991 were larger than in 1989. Mean length at age 2 in 1988 was similar to that in 1989. At ages 4 and 6, the mean lengths in 1988 were larger than those in 1989 and similar to 1991, and at age 8, the mean in 1991 was larger than the mean in 1988 (Table 2.22).

Length distributions for the study area from 1988-91 indicated three modes of abundance around 100 mm, 200 mm, and 300 mm (Figure 2.44B). As Dolly Varden char grew larger, sample sizes declined and distinct modes were lacking. Age frequencies showed a unimodal peak at age 4 (Figure 2.44A). Length frequencies by area indicated a bimodal distribution around 180 mm FL and between 280 and 400 mm FL (Figure 2.45). The corresponding age frequencies indicated a unimodal distribution around ages 4 and 5 except in Beaufort Lagoon where no apparent mode occurred. Yearly length frequencies indicated bimodal distributions except in 1989 where a unimodal curve peaked around 180 mm (Figure 2.46). Yearly age frequencies, similar to those by area, indicated a unimodal distribution around ages 4 and 5.

Movements

Between 1988 and 1991 we dye marked 5,529 Dolly Varden char. We had recaptured 193 char by 1992 (Table 2.23). Less than 5% of the recaptures were from sampling areas other than where they were initially captured and marked. Marked Dolly Varden char displayed movement between Camden Bay and the other three sampling areas, between Kaktovik and Jago lagoons and the other two sampling areas, and between Beaufort Lagoon and Simpson Cove.

We anchor tagged a total of 1,960 Dolly Varden char between 1988 and 1991 (Table 2.24). By the end of 1991, we had recaptured 101 Dolly Varden char

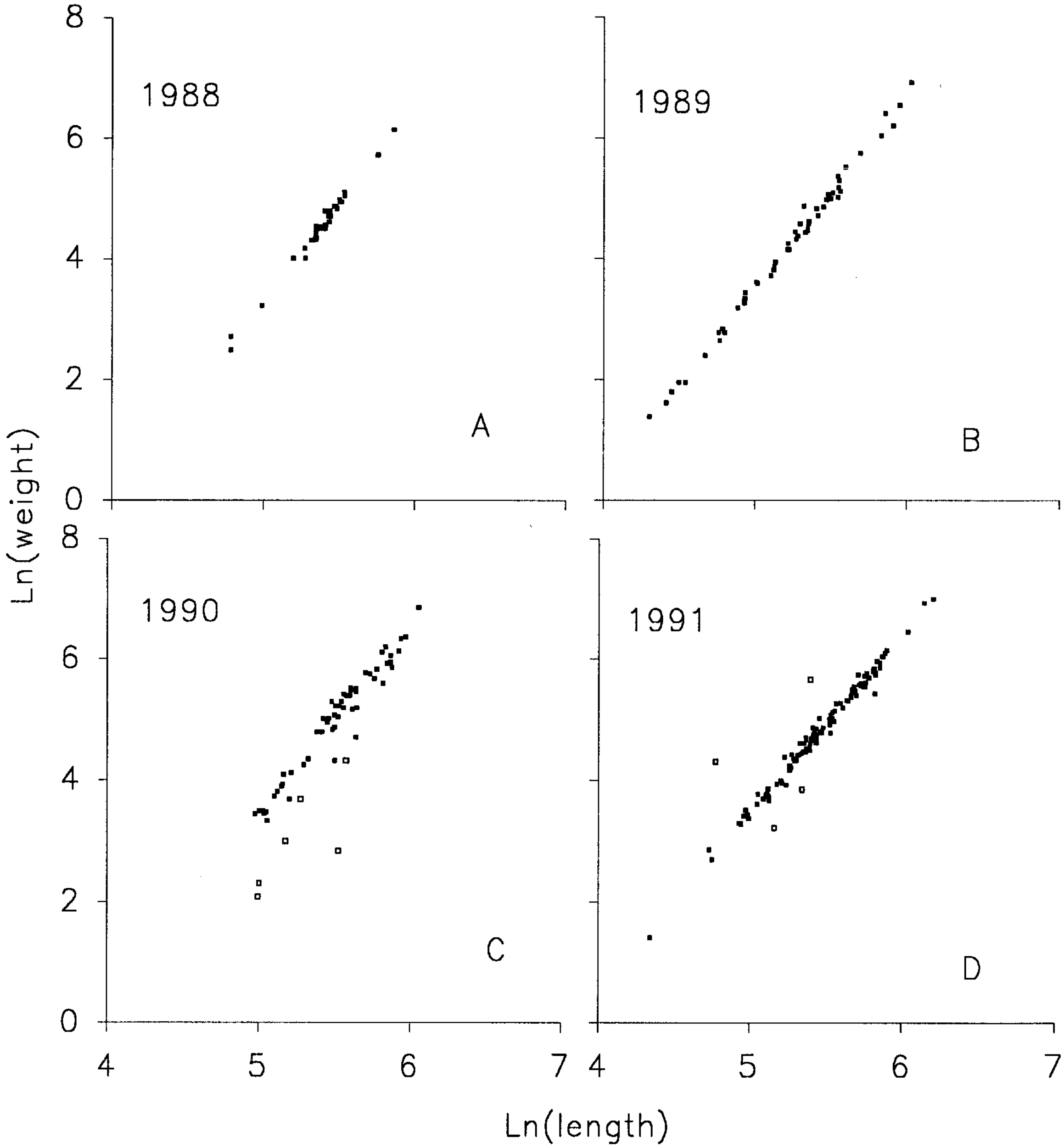

FIGURE 2.43.- Log-transformed Dolly Varden char weight-length data (□=outliers) collected after August 27 in all areas for comparison among-years.

TABLE 2.20.– Mean length at age (±SE) and ranges of Dolly Varden char collected during July, all years and areas pooled.

Age	*N*	$\bar{x}$(SE)	Range
1	10	96(4)	64-120
2	22	137(5)	102-184
3	37	205(9)	106-395
4	70	274(7)	171-420
5	55	339(7)	200-454
6	32	394(10)	308-545
7	18	437(14)	378-564
8	20	496(13)	306-580
9	13	499(24)	451-526
10	32	482(32)	450-553
11	16	540(13)	504-587
12	0	-	--
13	12	529(3)	526-532
	N = 277	$\bar{x}$ = 314.8	

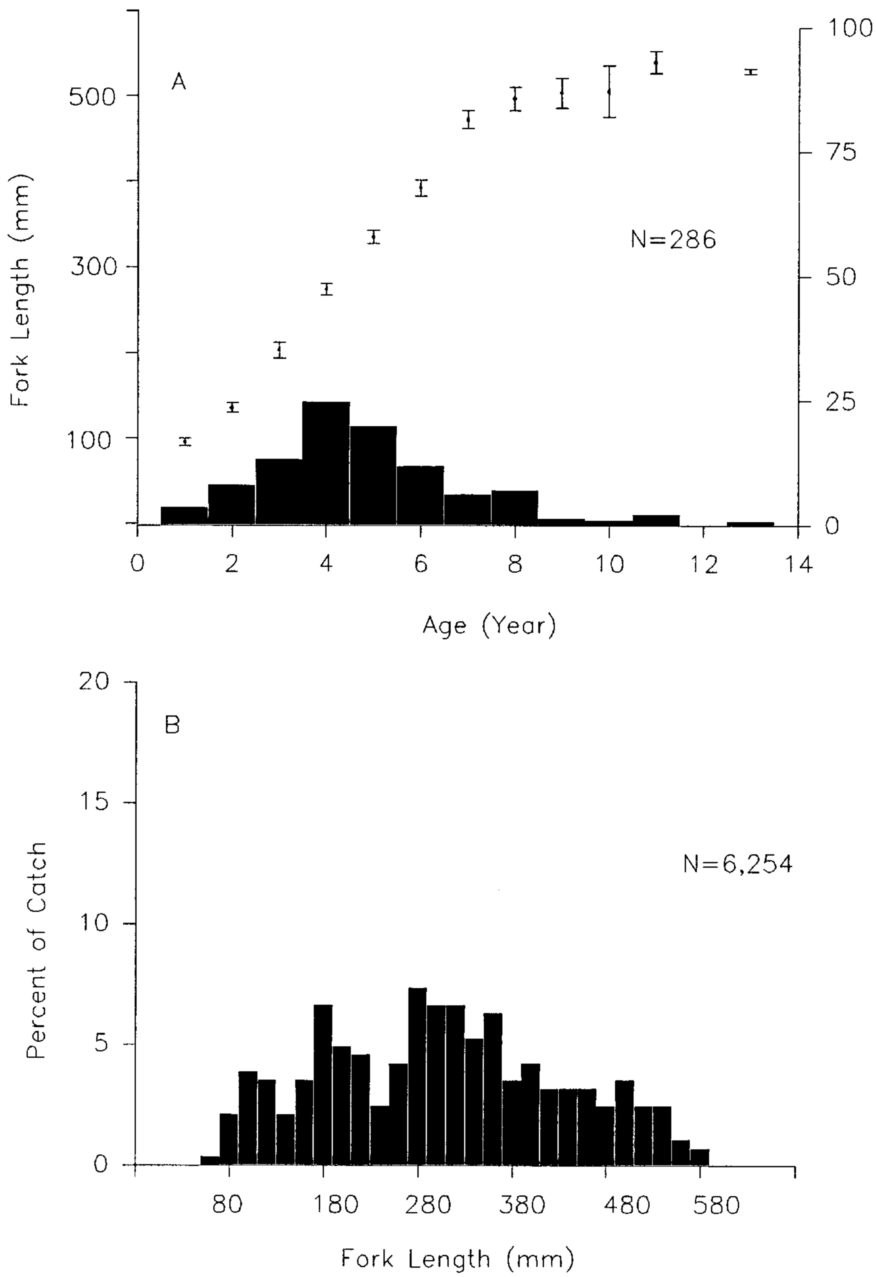

FIGURE 2.44.– Mean length at age (±SE), age frequency (A), and standard fyke net length frequencies (20 mm intervals) (B), for Dolly Varden char collected with years and areas pooled.

TABLE 2.21.– Mean lengths at age (±SE) for Dolly Varden char collected during July, 1988, 1989, and 1991. Kruskal Wallis significant difference (indicated by *) found among the areas at this age ($P<0.05$). Similar letters across a row represent no significant differences between those means.

	Simpson Cove			Jago Lagoon			Kaktovik Lagoon			Beaufort Lagoon		
Age	*N*	$\bar{x}$(SE)		*N*	$\bar{x}$(SE)		*N*	$\bar{x}$(SE)		*N*	$\bar{x}$(SE)	
1		--		5	94(0)			--		5	97(9)	
2*	3	166(8)	**A**	8	123(5)	**BC**	4	113(1)	**BC**	7	155(6)	**AB**
3	8	189(4)		8	194(15)		7	213(27)		14	216(19)	
4	25	277(12)		16	266(8)		17	264(15)		12	289(16)	
5	14	344(20)		5	349(20)		21	323(7)		15	351(12)	
6	10	375(10)			--		7	353(9)		14	435(14)	
7	9	478(12)			--		2	437(14)		7	475(20)	
8*	3	484(10)	**AB**		--		3	415(56)	**B**	14	516(10)	**A**
9	2	488(37)		1	519(--)			--			--	
10		--		1	450(--)		1	514(--)			--	
11	1	587(--)		1	505(--)		1	542(--)		3	535(16)	
12		--			--			--			--	
13		--			--			532(--)		1	526(--)	

TABLE 2.22.– Mean lengths (±SE) and ranges of Dolly Varden char collected during July, areas pooled. Kruskal Wallis significant difference (indicated by *) found among the years at this age (P<0.05). Similar letters across a row represent no significant differences between those ages.

Age	1988 *N*	1988 $\bar{x}$(SE)	1988 Range		1989 *N*	1989 $\bar{x}$(SE)	1989 Range		1991 *N*	1991 $\bar{x}$(SE)	1991 Range	
1	1	97(--)	97		4	93(0)	92-96		5	97(9)	64-120	
2*	5	119(9)	103-157	B	9	122(4)	102-151	B	9	159(6)	131-184	A
3	13	212(15)	132-310		8	173(13)	106-227		17	210(16)	126-395	
4*	14	293(13)	186-363	A	24	248(8)	171-309	B	33	284(10)	180-420	A
5	21	313(9)	218-400		10	351(9)	303-410		26	346(12)	200-454	
6*	10	355(7)	308-386	A	2	332(20)	312-353	B	22	415(11)	345-545	A
7	2	437(14)	423-452			--	--		16	477(11)	378-564	
8*	3	415(56)	306-496	B		--	--		17	511(9)	435-580	A
9	1	518(--)	518		2	485(34)	451-519		1	5(--)	526	
10	3	505(30)	450-553			--	--			--	--	
11	1	505(--)	505		1	542(--)	542		4		504-587	
12		--	--				--			--	--	
13	1	532(--)	532				--				526	

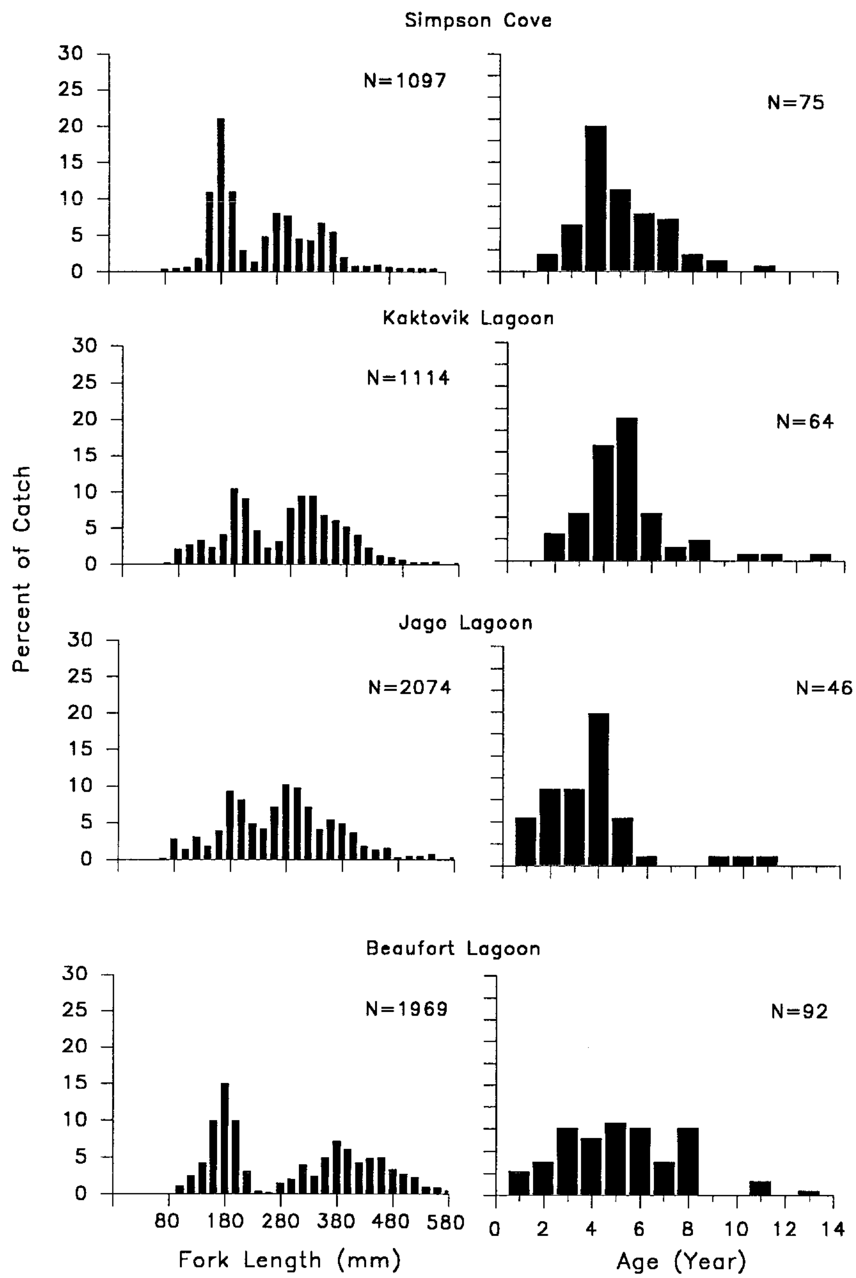

FIGURE 2.45.— Percent frequencies of length (20 mm intervals) for standard fyke net catches and of age for Dolly Varden char collected during July, 1988, 1989, and 1991 with years pooled.

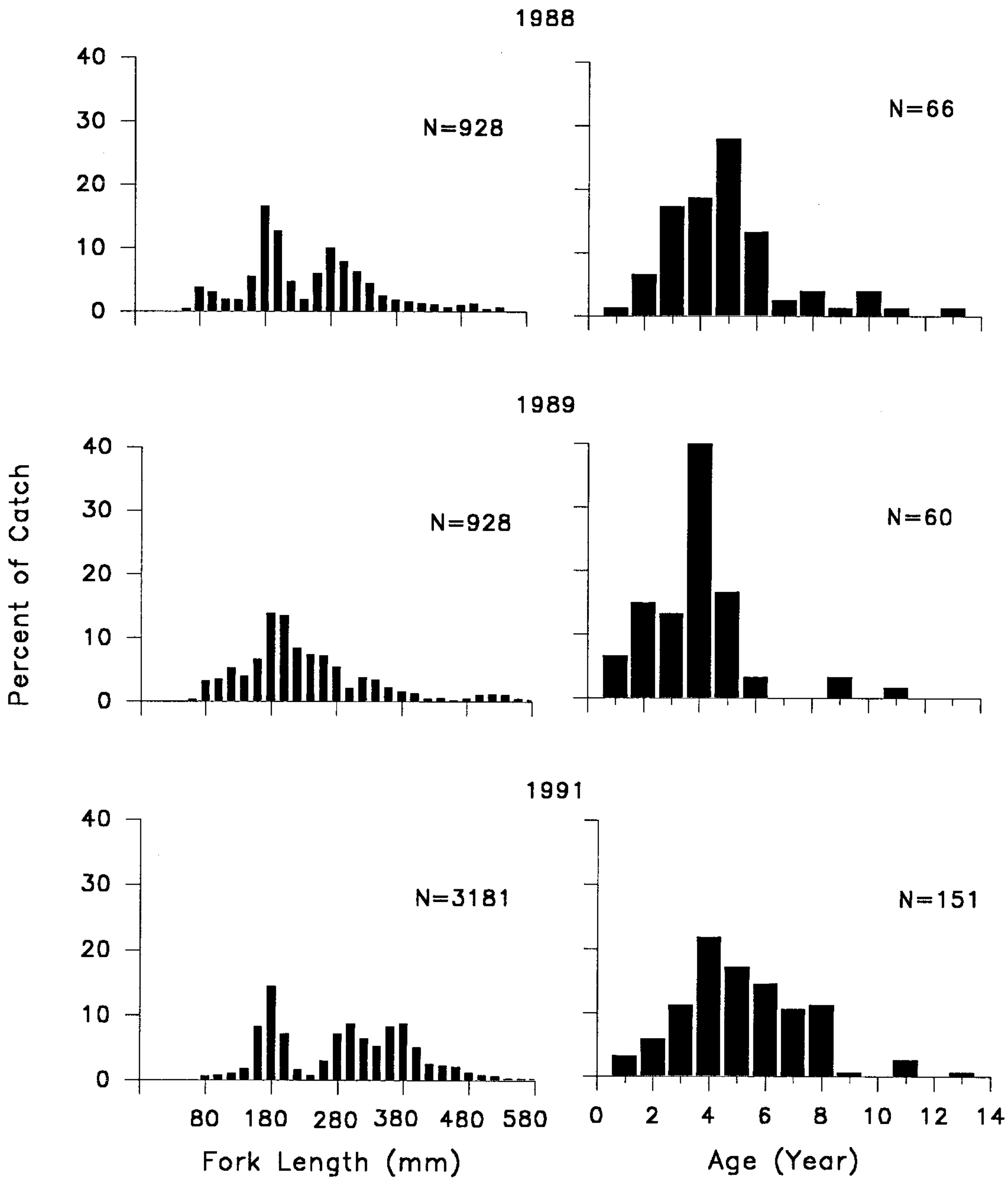

FIGURE 2.46.— Percent frequencies of length (20 mm intervals) for standard fyke net catches and of age for Dolly Varden char collected during July, 1988, 1989, and 1991 with areas pooled.

TABLE 2.23.— Number of Dolly Varden char dye marked (*N*) and recaptured by area during open water season on the Arctic Refuge, 1988-91.

		Recapture area			
Marking area	*N*	Simpson Cove	Kaktovik and Jago lagoons	Beaufort Lagoon	Pokok Bay
Simpson Cove	2009	21	1	1	0
Kaktovik / Jago	2436	1	106	2	0
Beaufort Lagoon	948	4	0	46	0
Pokok Bay	136	0	0	0	11

TABLE 2.24.— Number of Dolly Varden char tagged (*N*) and recaptured by location during the summer on the Arctic Refuge, 1988-91.

		Recapture area				
Tagging area	*N*	Simpson Cove	Kaktovik Lagoon	Jago Lagoon	Beaufort Lagoon	Pokok Bay
Simpson Cove	666	5	1	1	1	0
Kaktovik Lagoon	480	1	13	2	1	0
Jago Lagoon	427	2	6	9	0	0
Beaufort Lagoon	386	0	0	0	59	0
Pokok Bay	1	0	0	0	0	0

from refuge coastal waters. Less than 16% of the recaptures were from sampling areas other than where tags were applied. Tagged fish moved between Camden Bay and the Kaktovik and Jago lagoon complex, and from those areas to Beaufort Lagoon. Tagged char from Beaufort Lagoon were not recaptured west of there. Dolly Varden char traveled between sampling areas in as few as 28 d. Mark-recapture data documented that Dolly Varden char traveled between the Arctic Refuge lagoons and rivers on the refuge. In 1989, we recaptured two Dolly Varden char in coastal sampling areas which were originally tagged in Arctic Refuge rivers, one tagged in each of the Hulahula and Aichilik rivers. Conversely, in 1991, recreational anglers on the Hulahula and Kongakut rivers caught three char which had been tagged in coastal lagoons. In addition, tagged char were recaptured in Canada to the east and west of Prudhoe Bay in Simpson Lagoon.

Environmental Influences on CPUE

Simpson Cove.— When compared to all sampling areas, the relatively exposed waters of Simpson Cove reflected a predominately marine influence. Over the course of a sampling season, mean water temperatures in Simpson Cove were always as cold or significantly colder than the remaining areas, and salinities were typically higher (Table 2.25). Salinities in Simpson Cove were relatively high in 1988 and 1990 when compared to the other two study years (Figure 2.47).

Relationships between catch rates and hydrologic variables varied by year, and were weak associations at best. We documented strong correlations with temperature (positive) and salinity (negative) at station SC01 in 1988 (Figure 2.48), but only 10 sampling days were available for analysis. Coefficients of determination for most stepwise analyses (excluding 1988) were low (<0.45), except for station SC04 in 1990 (Tables 2.26, 2.27). Temperature appeared to be related to high Dolly Varden char catch rates at that station in 1990, while north wind components were associated with lower catch rates (Figure 2.48). Except for the weak 1990 pattern mentioned above, no discernible trends were evident from the distribution of catch rates over the sampled temperature ranges (Figure 2.49).

Jago Lagoon and Kaktovik Lagoon.— Although geographically very close, these two sampling areas exhibited somewhat different inter-annual temperature and salinity regimes throughout the study period (Figures 2.50, 2.51). Kaktovik Lagoon is generally less influenced by marine water masses than is Jago Lagoon (Hale 1990, 1991). As a reflection of this, Kaktovik Lagoon water temperatures were significantly warmer than those in Jago Lagoon in 1988 and 1990 (Table 2.26). Unfortunately, while synoptic accounts of the thermohaline environment in these two lagoons are available for the latter part of the 1988 sampling season, most of the Dolly Varden char catch occurred in the first half of the sampling season before CTD data were available.

We detected few consistent relationships between catch rates and hydrographic variables for either lagoon. Of the variables measured, north wind elements best described variation in Jago Lagoon catch rates in 1988 and 1989, while east wind components performed better in 1990 and 1991 (Table

TABLE 2.25.— Comparisons of daily Dolly Varden char CPUE (fish/d), mean daily water temperature (C), and mean daily salinity (ppt) between sampling areas, 1988-91. Areas connected by a common underline are not significantly different (ANOVA, Scheffé multiple comparisons, α=0.05). Where different, areas are ordered from larger to smaller mean values for the comparison variable.

Variable	Scheffé grouping			
		1988		
CPUE	Kaktovik	Simpson	Jago	Pokok
Temp.	Kaktovik	Jago	Pokok	Simpson
Salinity	Simpson	Kaktovik	Jago	Pokok
		1989		
CPUE	Kaktovik	Jago	Simpson	
Temp.	Jago	Kaktovik	Simpson	
Salinity	Simpson	Jago	Kaktovik	
		1990		
CPUE	Jago	Kaktovik	Simpson	Beaufort
Temp.	Beaufort	Kaktovik	Simpson	Jago
Salinity	Simpson	Jago	Beaufort	Kaktovik
		1991		
CPUE	Simpson	Kaktovik	Beaufort	Jago
Temp.	Beaufort	Kaktovik	Jago	Simpson
Salinity	Simpson	Kaktovik	Jago	Beaufort

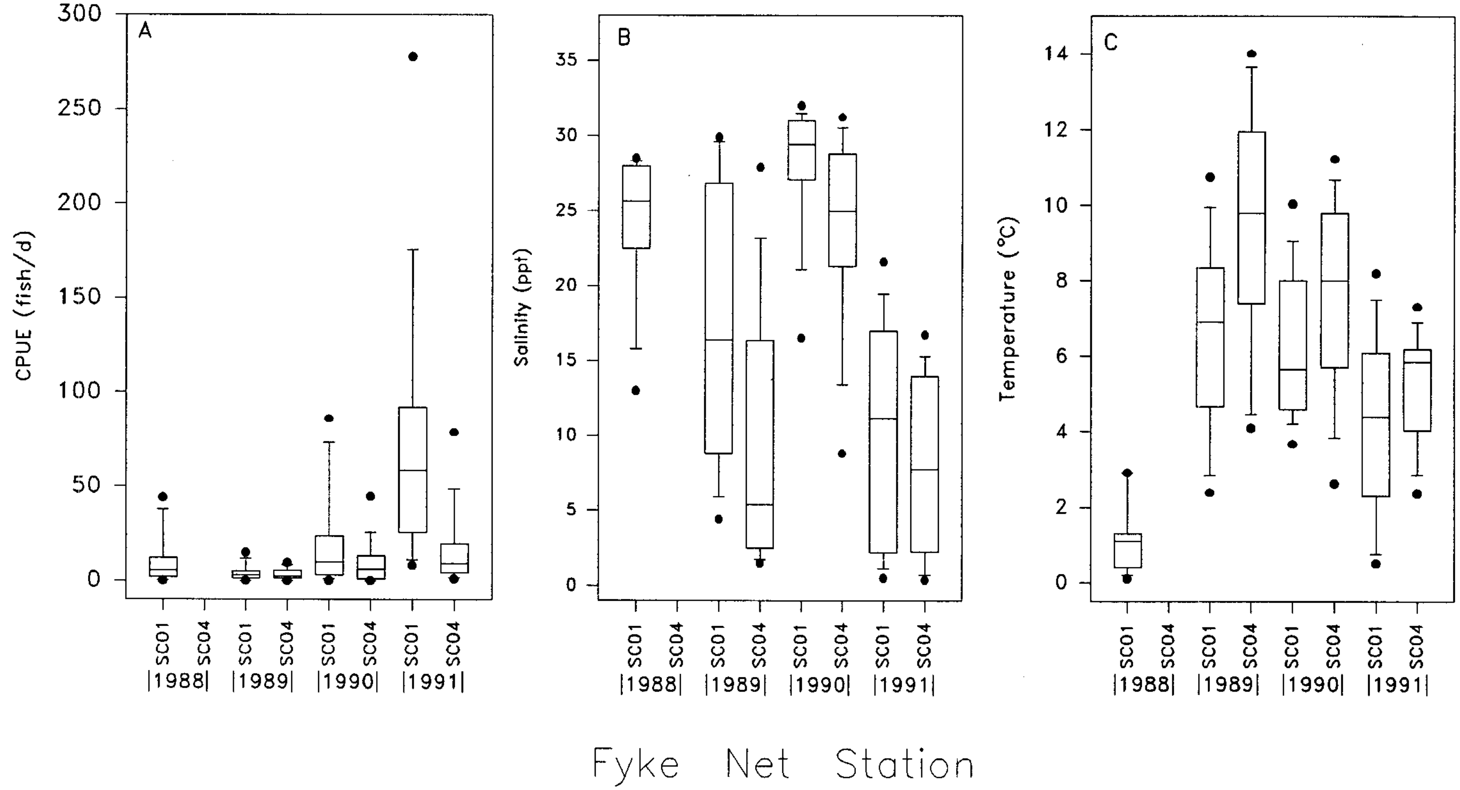

FIGURE 2.47.– Boxplots of (A) catch per unit effort for Dolly Varden char, (B) salinity, and (C) temperature for Simpson Cove fyke net stations during 1988-91.

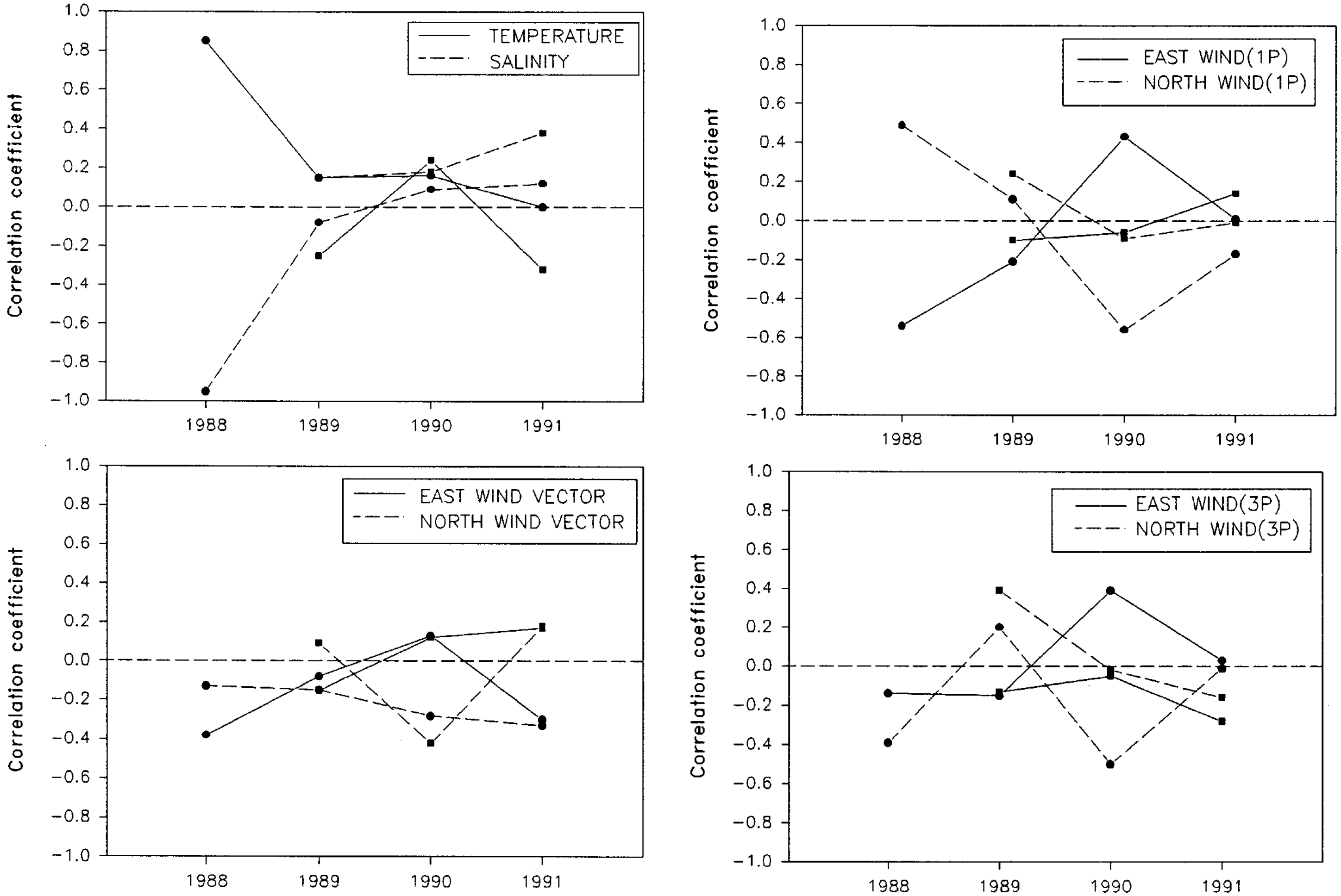

FIGURE 2.48.– Correlations between environmental variables and char CPUE from fyke net stations SC01 (•) and SC04 (■) (1988-91) in Simpson Cove. [1P=mean wind vector for previous day; 3P=mean wind vector over 3 previous days].

TABLE 2.26.– Environmental variables[a] influencing Dolly Varden char CPUE (fish/d), followed by R^2 value of overall model. Parameter estimate is positive unless followed by "(-)". ["nv" = no eligible variables.]

Station	1988	1989	1990	1991
		Simpson Cove		
SC01	SAL(-) NW(-) (0.90)	EW1P(-) NW(-) (0.13)	EW3P NW3P(-) (0.42)	nv
SC04		NW3P (0.20)	TEMP NW3P NW(-) (0.52)	SAL (0.34)
		Kaktovik Lagoon		
KL05	TEMP (0.53)	SAL(-) TEMP(-) (0.48)	EW1P (0.40)	EW TEMP EW1P (0.55)
KL10	TEMP(-) (0.25)	NW(-) (0.06)	NW3P(-) (0.17)	TEMP NW(-) (0.30)
		Jago Lagoon		
JL12	NW3P EW (0.36)	SAL(-) NW3P TEMP(-) (0.39)	nv	NW EW (0.41)
JL14	SAL(-) (0.23)	SAL(-) (0.08)	EW3P NW3P(-) SAL TEMP(-) (0.59)	EW1P (0.21)
		Beaufort Lagoon		
BL02			NW (0.24)	TEMP EW1P(-) SAL(-) (0.70)
BL04			SAL NW3P(-) TEMP (0.37)	TEMP EW(-) NW1P(-) (0.66)
		Pokok Bay		
PB01	TEMP (0.21)			
PB02	TEMP EW (0.49)			

[a] EW=mean east wind vector; EW1P=mean east wind vector for previous day; EW3P=mean of east wind vector over 3 previous days; NW=mean north wind vector; NW1P=mean north wind vector for previous day; NW3P=mean north wind vector over 3 previous days; SAL=salinity(ppt); TEMP=temperature(C).

TABLE 2.27.- Environmental variables[a] influencing Dolly Varden char CPUE (pooled over stations). Coefficient of partial correlation (r^2_p) for each effect and overall R^2 shown as determined by stepwise selection procedure.

Year	Environmental variable	r^2_p	R^2
	Simpson Cove		
1988	SAL	0.89	
	NW	0.40	0.90
1989	NW3P	0.09	
	EW1P	0.04	0.12
1990	EW3P	0.14	0.14
1991	SAL	0.24	
	EW	0.05	0.27
	Kaktovik Lagoon		
1988	TEMP	0.11	0.11
1989	SAL	0.09	
	TEMP	<0.01	0.09
1990	EW3P	0.19	0.19
1991	TEMP	0.18	
	EW1P	0.08	0.24
	Jago Lagoon		
1988	NW3P	0.15	0.15
1989	NW3P	0.08	
	SAL	0.06	0.13
1990	EW3P	0.28	
	EW	0.12	
	TEMP	0.01	0.35
1991	EW1P	0.19	0.19
	Beaufort Lagoon		
1990	EW	0.11	
	EW3P	0.07	
	NW1P	0.06	0.21
1991	TEMP	0.52	
	EW	0.18	
	EW1P	0.07	
	SAL	0.03	0.59
	Pokok Bay		
1988	TEMP	0.27	0.27

[a] EW=mean east wind vector; EW1P=mean east wind vector for previous day; EW3P=mean of east wind vector over 3 previous days; NW=mean north wind vector; NW1P=mean north wind vector for previous day; NW3P=mean north wind vector over 3 previous days; SAL=salinity(ppt); TEMP=temperature(C).

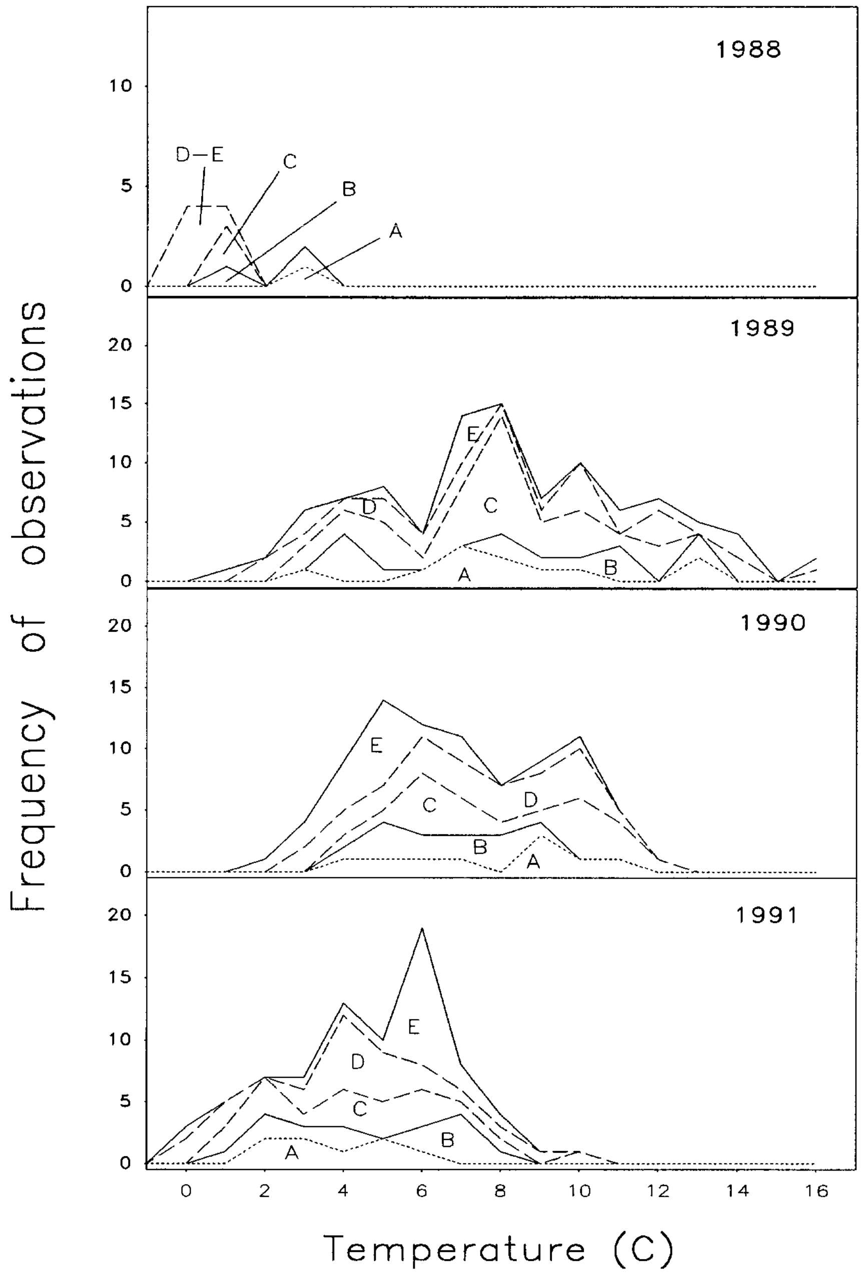

FIGURE 2.49.— Frequency of occurrence, by mean daily water temperature, of top 10 (A), 25 (B), 50 (C), 75 (D), and 100 (E) percentile catch per effort data points for Dolly Varden char in Simpson Cove, 1988-91.

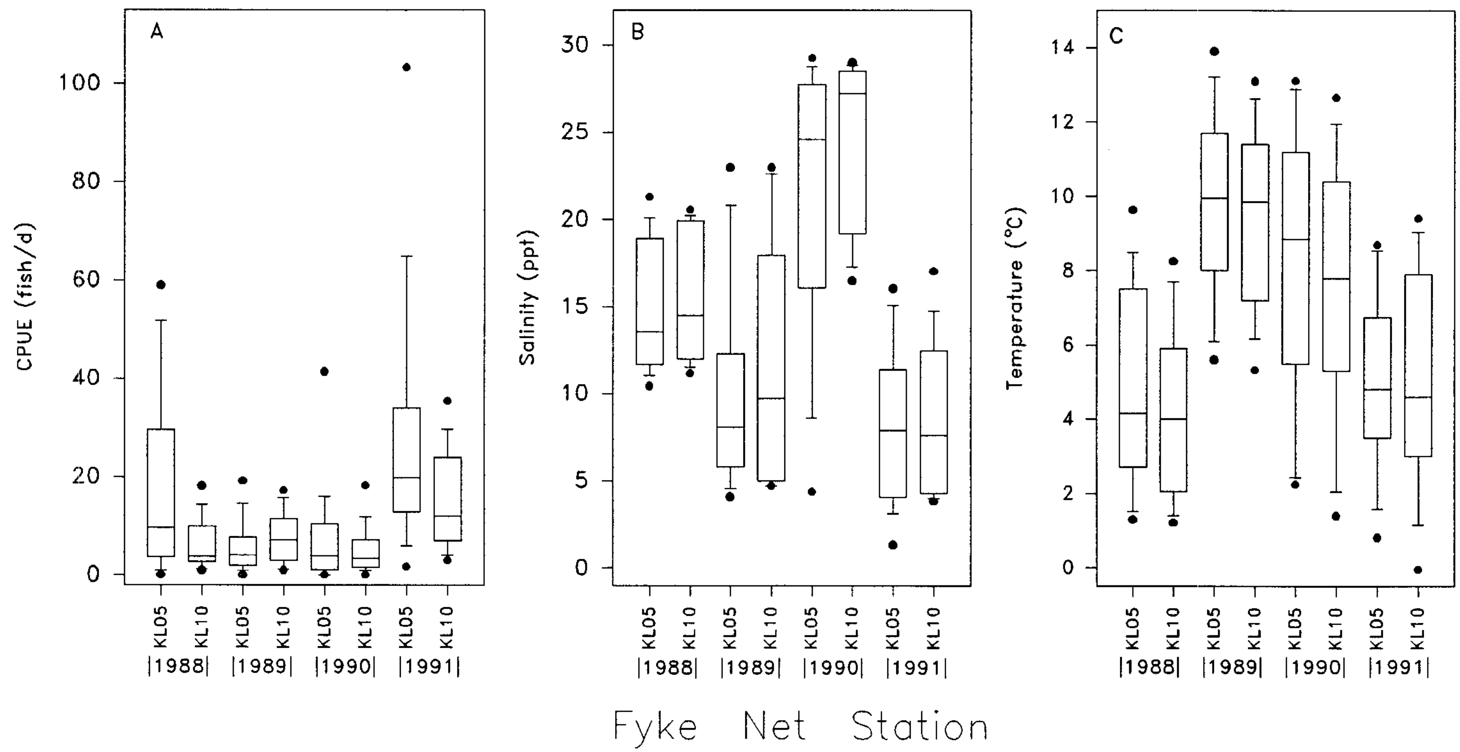

FIGURE 2.50.– Boxplots of (A) catch per unit effort for Dolly Varden char, (B) salinity, and (C) temperature for Kaktovik Lagoon fyke net stations during 1988-91.

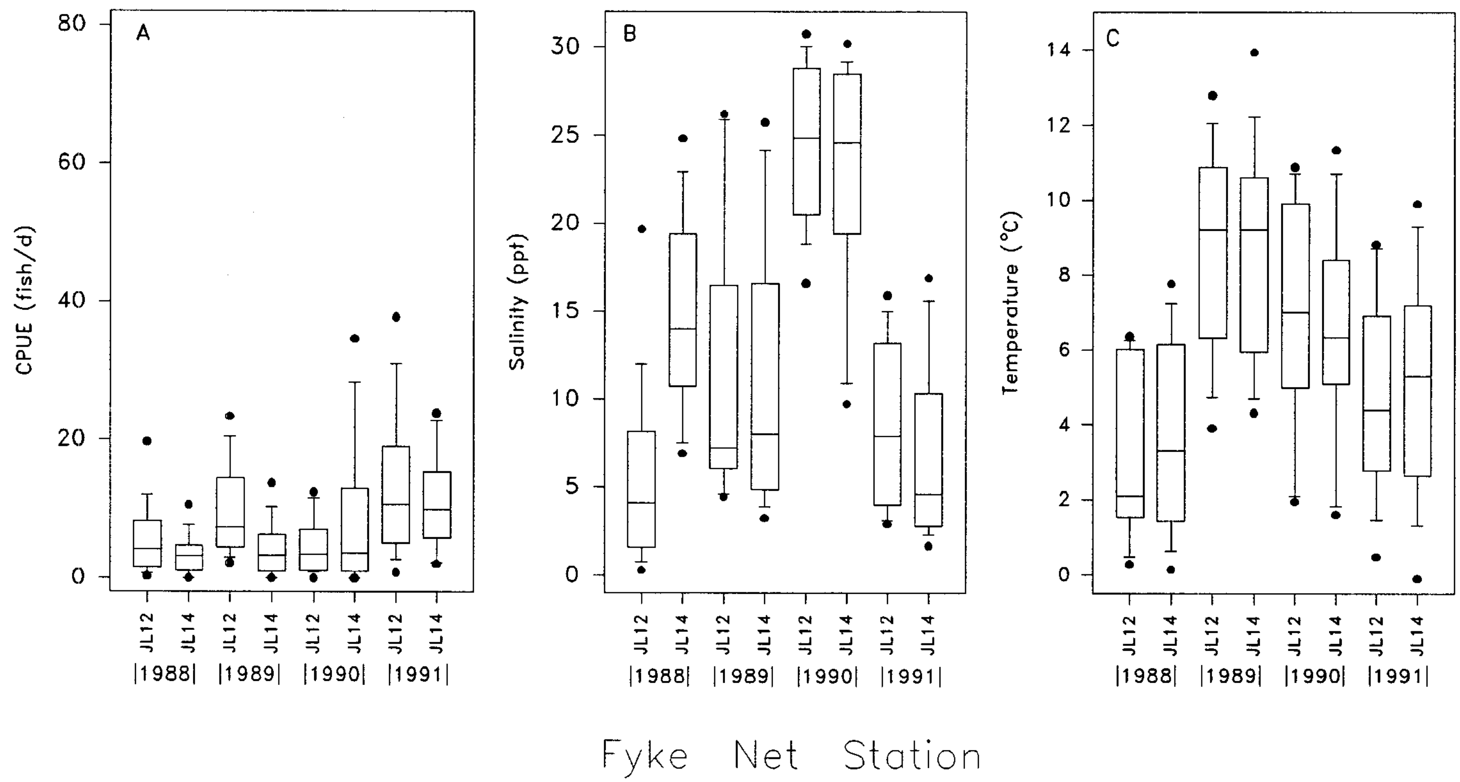

FIGURE 2.51.– Boxplots of (A) catch per effort for Dolly Varden char, (B) salinity, and (C) temperature for Jago Lagoon fyke net stations during 1988-91.

2.27). Catch rates were positively correlated with north wind elements in 1988-89 and with east wind elements in 1990-91 (Figure 2.52). Except for 1990, however, relationships for station and area-wide analyses were weak in Jago Lagoon (Tables 2.26, 2.27) with coefficients of determination less than 0.40. A positive relationship between 1990 catch rates at station JL14 and east winds resulted in a relatively high R^2 (0.59).

The distribution of catch rates over available temperatures revealed no discernible trend (Figure 2.53). We observed similar correlative trends in Kaktovik Lagoon over the course of the study period, particularly the sign reversal in correlations between east wind and north wind components between 1989 and 1990 (Figure 2.54). At station KL05, where R^2-values approached meaningful levels, temperature (positive relationship) and salinity (negative relationship) appeared to best explain variation in Dolly Varden char catch rates, whereas a direct relationship with east wind components became significant in 1990 and 1991 (Table 2.26). This interannual pattern of associations was also evident in the area-wide analysis (Table 2.27). The highest catch rates in 1988 appeared to be distributed over the high end of the available temperature range (Figure 2.55), strengthening the argument that catch rates were positively related to water temperatures in Kaktovik Lagoon during that year.

Beaufort Lagoon.– Water temperatures and salinities in Beaufort Lagoon were influenced by riverine input (primarily the Aichilik River) when compared to the other sampling areas. Within a sampling season, Beaufort Lagoon generally exhibited higher temperatures (1990) or lower salinities (1991) than did the remaining sampling areas (Table 2.25). In 1990, Dolly Varden char CPUE was significantly lower in Beaufort Lagoon than in other sampling areas, and no strong relationships between area or station CPUE and prevailing hydrographic conditions were apparent. A north wind vector influence was evident for both fyke net stations, while salinity and temperature were also useful in explaining CPUE variability at station BL04 (Table 2.26). When station data were combined, east wind and north wind vector components were the most successful explanatory variables (Table 2.27); however, the coefficients of determination for both station (BL02 R^2 = 0.24; BL04 R^2 = 0.37) and area (R^2 = 0.21) modeling efforts indicated weak relationships at best in the 1990 data.

Contrary to the 1990 results, we detected relatively strong CPUE-hydrographic relationships for Dolly Varden char in Beaufort Lagoon during 1991. Correlation coefficients between CPUE and both temperature and salinity increased dramatically in absolute magnitude from 1990 to 1991 (Figure 2.56). We detected a positive relationship between temperature and CPUE for both station and area-wide stepwise regression analyses (Tables 2.26, 2.27). The partial correlation coefficient for temperature (0.52) and the overall R^2 of 0.59 in the area-wide analysis were the strongest such relationships detected in data sets with N > 10. The same is true for the 1991 station-specific R^2 values. The relationship between CPUE and water temperature was further demonstrated by the distribution of intraseasonal CPUE values over the temperature range at which samples were collected (Figure 2.57). The highest CPUE values occurred on the right side of the overall

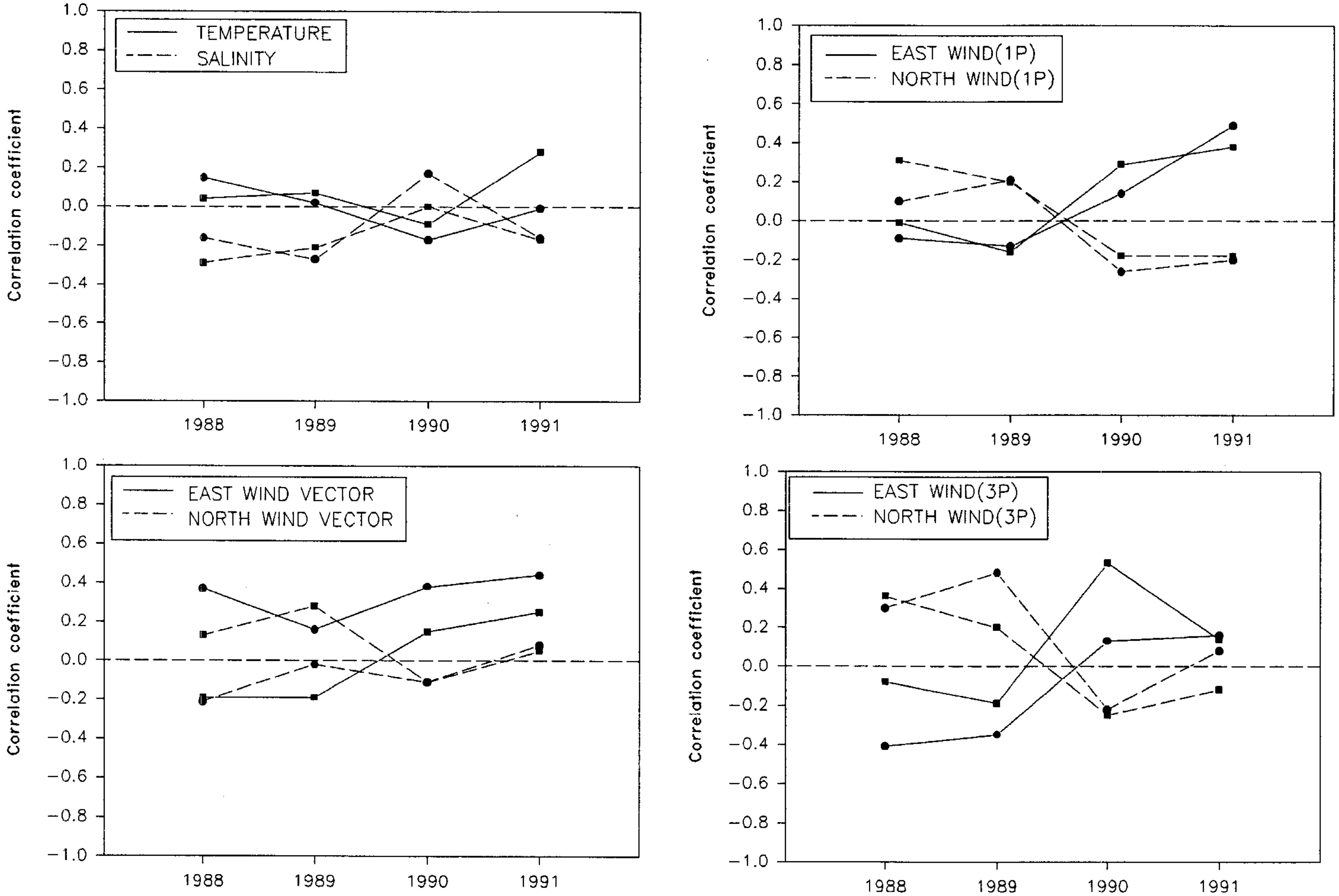

FIGURE 2.52.– Correlations between environmental variables and char CPUE from fyke net stations JL12 (•) and JL14 (▪) in Jago Lagoon, 1988-91. [1P=mean wind vector for previous day; 3P=mean wind vector over 3 previous days].

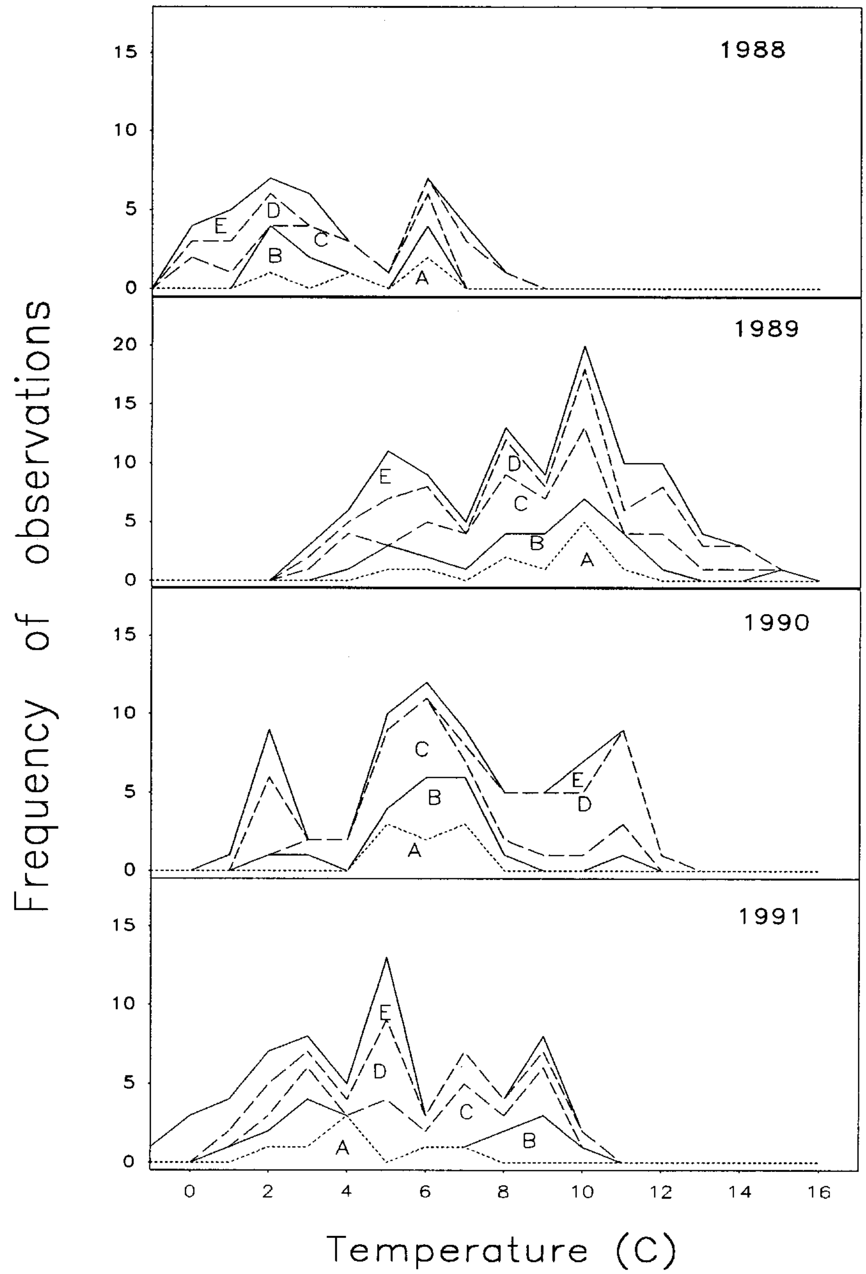

FIGURE 2.53.— Frequency of occurrence, by mean daily water temperature, of top 10 (A), 25 (B), 50 (C), 75 (D), and 100 (E) percentile catch per effort data points for Dolly Varden char in Jago Lagoon, 1988-91.

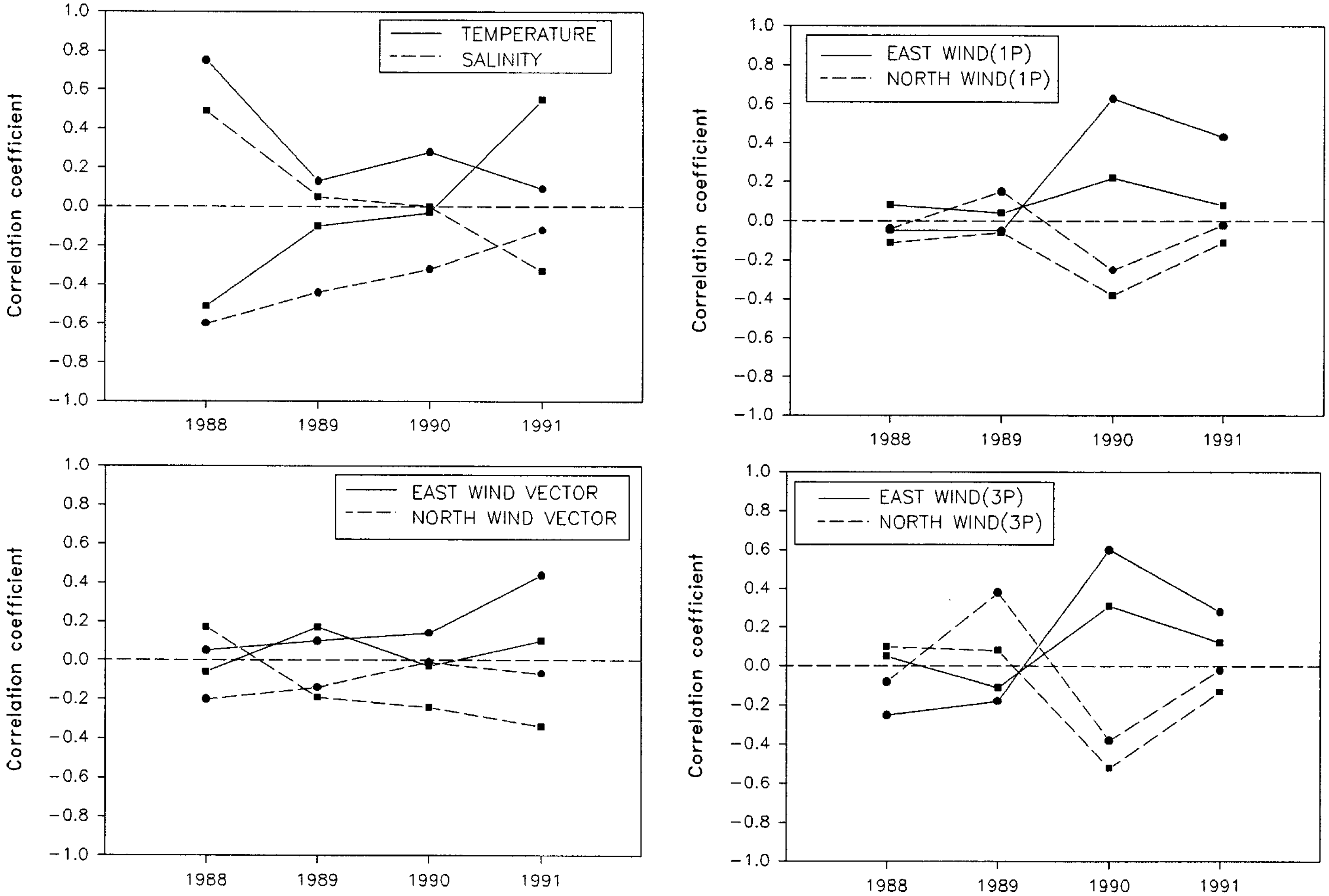

FIGURE 2.54.— Correlations between environmental variables and char CPUE from fyke net stations KL05 (•) and KL10 (■), in Kaktovik Lagoon, 1988-91. [1P=mean wind vector for previous day; 3P=mean of wind vector over 3 previous days].

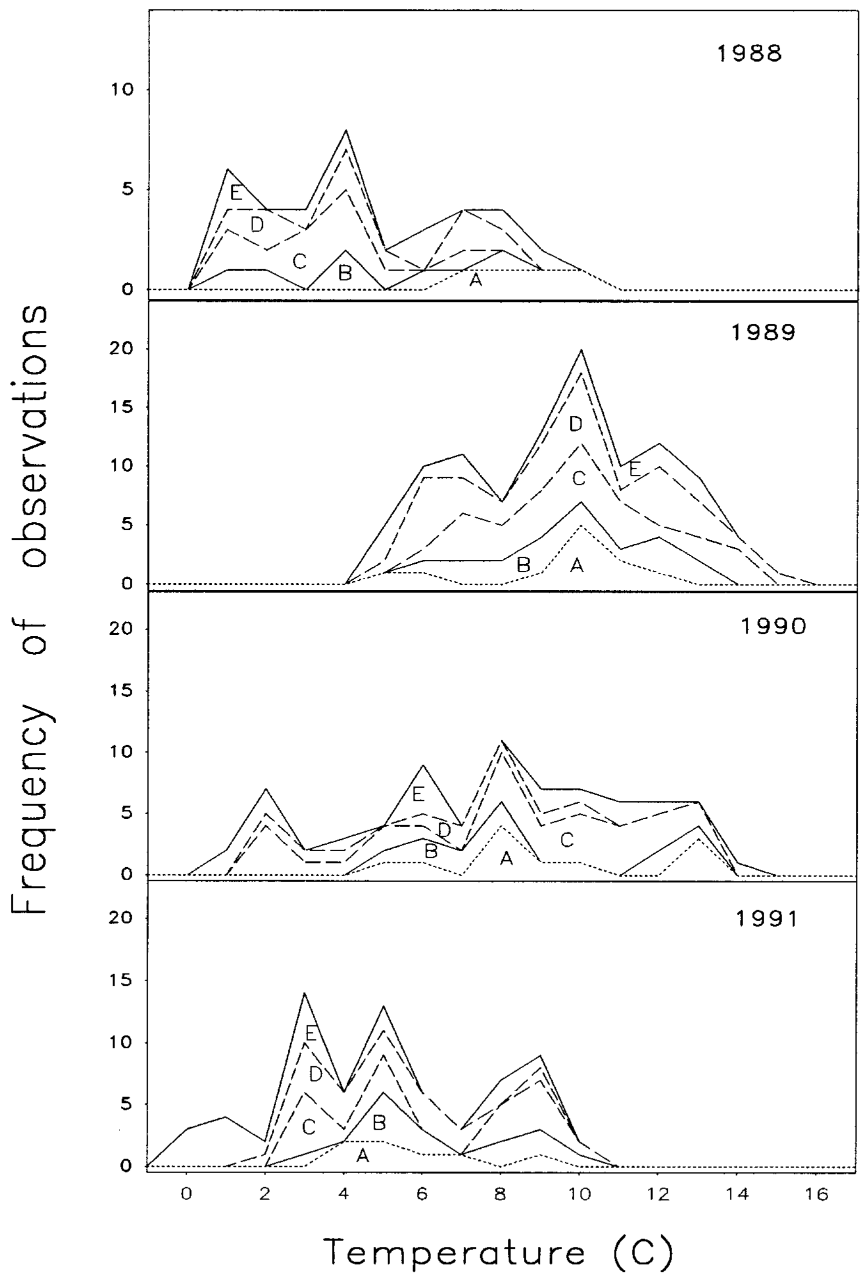

FIGURE 2.55.— Frequency of occurrence, by mean daily water temperature, of top 10 (A), 25 (B), 50 (C), 75 (D), and 100 (E) percentile catch per effort data points for Dolly Varden char in Kaktovik Lagoon, 1988-91.

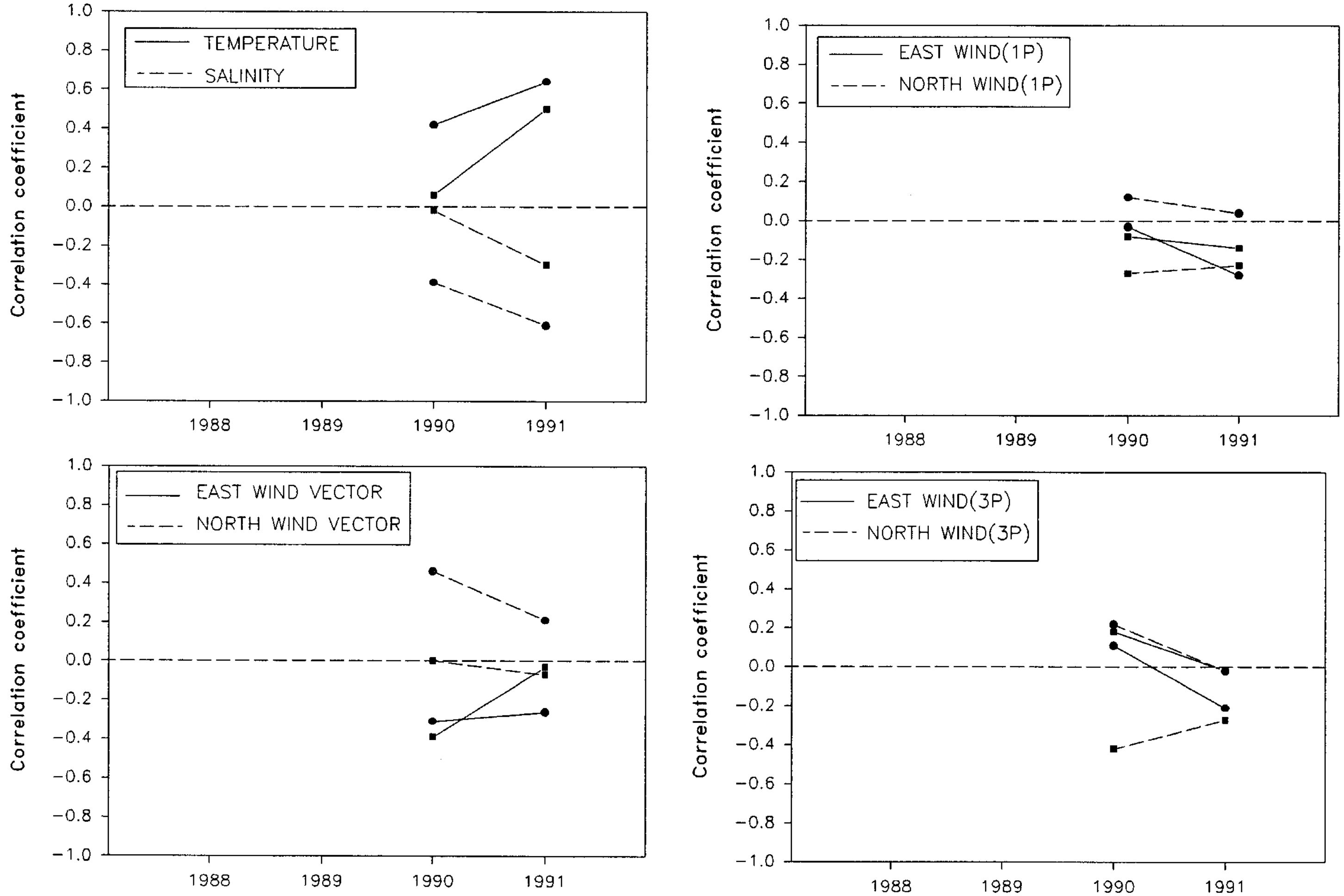

FIGURE 2.56.— Correlations between environmental variables and char CPUE from fyke net stations BL02 (•) and BL04 (▪) in Beaufort Lagoon, 1990-91. [1P=mean wind vector for previous day; 3P=mean wind vector over 3 previous days].

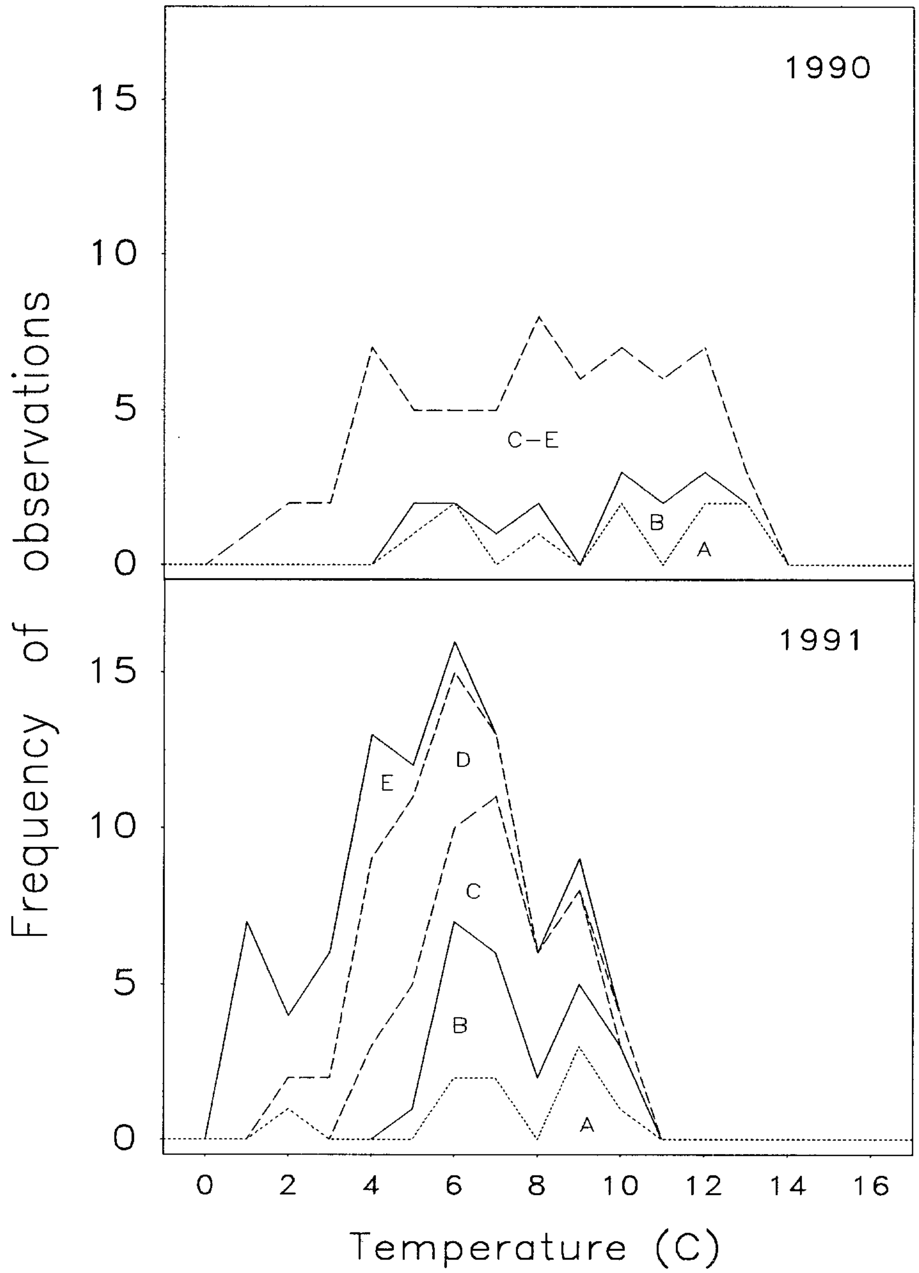

FIGURE 2.57.— Frequency of occurrence, by mean daily water temperature, of top 10 (A), 25 (B), 50 (C), 75 (D), and 100 (E) percentile catch per effort data points for char in Beaufort Lagoon, 1990-91.

distribution (i.e., the higher temperatures), while the lower catch rates expanded the distribution to the left toward the lower temperatures. Beaufort Lagoon salinities were also much lower during the 1991 sampling when temperature appeared to influence catch rates (Figure 2.58). Wind vector elements continued to show little correlation with CPUE patterns (Figure 2.56).

Pokok Bay.— Dolly Varden char catch rates appeared to be positively related to temperature in Pokok Bay in 1988 (Tables 2.26, 2.27), although the area-wide association was relatively weak ($R^2 = 0.27$). The distribution of CPUE over the sampled temperature range again demonstrates that the highest catch rates occurred at the highest temperatures. While temperature and salinity regimes in Pokok Bay did not differ from the Jago and Kaktovik sampling areas (Table 2.25), Dolly Varden char catch rates were significantly lowest in Pokok Bay.

Discussion

Relative Abundance and Distribution

Two-way ANOVA.— Identifying the major sources of variation is an important objective in baseline studies of abundance and distribution of fish populations. Our results suggest that, during the four years of this study, year-to-year variation in Dolly Varden char catch rates was greater than was spatial variation across years. Assuming a consistent sampling methodology, the results show that Dolly Varden char numbers in Arctic Refuge coastal waters varied more from year to year than from sampling area to sampling area. A possible explanation is that annual foraging and migration patterns differed greatly for some reason, thus rendering Dolly Varden char not equally available to our fyke nets in each year. This explanation would be reasonable if offshore waters were energetically or physiologically more suitable for Dolly Varden char during one or more sampling seasons, and significant numbers of fish were dispersed outside the range of our gear. Retention of a significant pack ice cover through summer months, as occurred in 1991 and 1988, may influence foraging and migration patterns of anadromous fishes by concentrating them in the nearshore open water lead. The high catch rates in shoreline fyke nets observed in 1991 and 1988 would be expected if Dolly Varden char were less likely to disperse under the pack ice.

Houghton et al. (1990) addressed the question of how variable environmental conditions may affect CPUE patterns and concluded that habitat use patterns of anadromous fishes, as measured by fyke nets, were not significantly affected by large fluctuations in temperature and salinity. Their results support the premise that differential abundance, not variable catchability in response to environmental cues, is primarily responsible for the annual variability observed in catch rates. As such, future studies should recognize the presence of significant annual variability in Dolly Varden char abundance and should account for this effect in data interpretations. Inferences concerning relative abundances of anadromous fishes in Beaufort Sea coastal waters must incorporate long-term data rather than relying on point estimates from

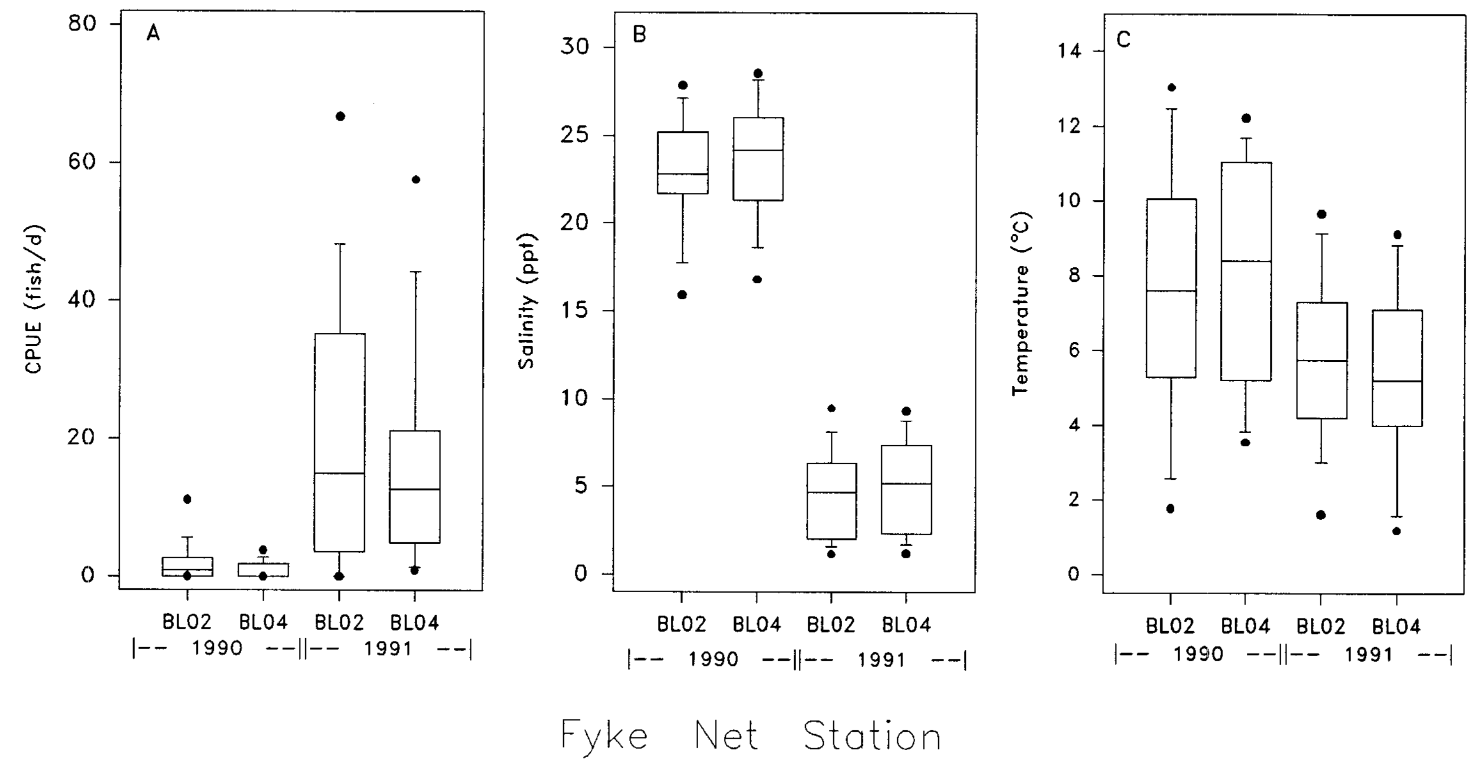

FIGURE 2.58.– Boxplots of (A) catch per effort for Dolly Varden char, (B) salinity, and (C) temperature for Beaufort Lagoon fyke net stations during 1990-91.

relatively short sampling periods. Furthermore, it is likely that variability would mask any trend and that population monitoring should be done at the spawning ground or in overwintering rivers where abundance would be more stable.

***Spatial differences*.**— We documented spatial variability in daily catch rates. Daily catch rates in Simpson Cove, the western sampling area, were higher than those for the eastern sampling area in 1988 (Pokok Bay), 1990, and 1991 (Beaufort Lagoon). No other consistent variability was evident. Lack of discernible trends could be due to environmental fluctuations, differential prey concentrations, or an interaction between these factors. Long time series of data are essential for the determination of biological trends or cycles.

***Temporal differences*.**— Craig and McCart (1976) noted movement of Dolly Varden char from fresh water into coastal waters from late May to June, and then a return to overwintering freshwater habitats prior to freeze-up. Decreasing daily catch rates within each sampling area during the four time periods support this theory on temporal variability of Dolly Varden char abundance. Low initial catch rates, as in Jago Lagoon in 1990, could be indicate of delayed movement into coastal waters. The lack of differences in daily catch rates within the open-water season, for example Simpson Cove in 1989, could indicate poor conditions with low migration into coastal waters. This stability in relative abundance might also be a result of good conditions when sampling occurred after migration into coastal waters was completed and was concluded before migration into freshwater commenced. This dual interpretation of the results is an example of the need for a better understanding of how environmental conditions affect abundance and distribution of Dolly Varden char populations.

***Implications*.**— Trends in relative abundance observed in this study identify potential concerns for future sampling. The high variability in daily catch rates between sampling locations indicates the need for exact identification of probable oil and gas development sites and intensive monitoring of these sites. These sites should be sampled with multiple net stations, greater than two, to provide an adequate description of fish abundance and distribution in the area.

Long time series of data (i.e., greater than 10 years) may be needed to discern abundance cycles normally associated with slow growing, cold water species. Identifying interannual patterns and trends in relative abundance is also dependent on collecting continuous time series of data with a consistent sampling design. Building a comprehensive database with long term data is essential for providing the baseline information necessary to assess potential impacts of oil and gas development. The current data base is not sufficient to meet assessment needs.

Length Frequency Distributions

Length frequencies for Dolly Varden char on the coast of the Arctic Refuge showed some similarities within and among years. First, primary modes tended to occur around 200 mm FL during July. The distributions then generally shifted to the right to 240 mm FL in early August and remained around that length through the end of the sampling period in September (Figures 2.30D, 2.30H, 2.31D, 2.31H). This pattern indicated summer growth.

A consistent mode at lengths > 400 mm FL occurred during July in Beaufort Lagoon. The presence of this mode indicates that large, possibly mature, Dolly Varden char travel through Beaufort Lagoon early in the season (Figures 2.36, 2.37). A small percentage of Dolly Varden char > 400 mm FL occurred in the other areas, mostly before August 16. These large Dolly Varden char may have been moving out of nearby overwintering river systems such as the Aichilik, Kongakut, and Hulahula rivers where they overwintered into the rich feeding areas of the lagoons and coastal waters (Craig 1984).

Conversely, annual patterns in several areas indicated migration, by larger Dolly Varden char during August, out of the study areas. Large fish were present earlier in the season and tended to be absent by September. For example, in 1989 and 1991 secondary modes at lengths > 400 mm FL appeared in Simpson Cove until 15 August. A similar pattern occurred in 1991 in Kaktovik Lagoon. Life history information indicates that Dolly Varden char migrate into freshwater rivers prior to spawning and overwintering. The early movement of larger Dolly Varden char into coastal drainages has been indicated in other studies (Craig 1984, 1989). Present-year spawners may begin their return quite early in the season (Craig 1989).

Dolly Varden char length frequency distributions also differed among years. In July, primary modes in length frequency of Dolly Varden char varied from 100 to 200 mm FL. In samples from July 9 to 31, modes occurred at approximately 100 mm FL in 1988 and 1989; however, primary modes first occurred at approximately 200 mm FL in 1990 and 1991 (Figures 2.30C-D). Inconsistent recruitment could explain the lack of small Dolly Varden char in the distribution.

Condition

Our results represent a departure from previously published reports regarding Dolly Varden char condition. Whitmus et al. (1987) reported no temporal or spatial differences in Dolly Varden char condition, but also stated that because of sampling regimes, condition analyses may have been "seriously biased" for that and previous studies. Colonell and Gallaway (1990) concluded that few statistical differences in condition were observed in anadromous fish in Arctic Alaska and that even less were biologically significant. Gallaway et al. (1991) found no temporal differences in Dolly Varden char condition or form in the Prudhoe Bay, Alaska, region during 1985 to 1987. However, these fish were sampled over the entire open-water season. Sampling over the entire season would increase variation, reduce precision and decrease the ability to detect changes in condition.

Dolly Varden char life history includes the wide dispersal of overwintering populations from rivers to nearshore coastal waters in the summer (Craig and McCart 1976; McCart 1980). This dispersal effectively mixes various anadromous stocks and we sampled these mixed stocks in our study. In addition, we documented tagged Dolly Varden char moving between our sampling areas within one month of tagging. We also observed Dolly Varden char, tagged in previous years, in areas other than where they were tagged (this study). With such mixing, one would expect little if any variation among areas. Therefore, detected changes in the slope coefficient of Dolly Varden char are probably not the result of different stocks, but more likely because equivalent stanzas were not available for each sample (Bagenal and Tesch 1978). Plots of linearized data indicate slight dissimilarity (Figures 2.39-2.43). Those size groups available to be sampled differed by area and year. The effects of availability are not yet clear. Similar differences in data plots were evident in data presented by LGL Alaska (1990a) and apparently had no effect on slope comparisons.

Gender differences.— We expected the combined year results to show sex-based differences in condition. Differences in weight-length relationships are often observed between female and male fish (Bagenal and Tesch 1978; Anderson and Gutreuter 1983). Differences in condition may be the result of dimorphism, life history, or stage of maturity. Dimorphism was not indicated in pre-analysis assessments; however, life history and stage of maturity were thought to be potential sources of variation. Dolly Varden char in Arctic Refuge coastal waters may not exhibit a sex-based difference in condition, or possibly, the study design prevented detection.

Gender-based differences caused by gonadal development are common. Current-year spawners would most likely exhibit differences, but these fish may not have reached an advanced stage of ripeness prior to leaving the coastal waters for the spawning grounds. Larger differences in condition would be expected as the time of spawning approached. Segregation from non-spawners, those fish still in coastal waters, would prevent detection of condition differences. Evidence for segregation of spawners includes observations in 1989 and 1991 that 8% and 4%, respectively, of mature female Dolly Varden char were considered current-year spawners by visual examination of the gonads: few ripe Dolly Varden char were sampled in coastal waters.

Additional testing for sex-based differences of condition should include concurrent samples from coastal waters and spawning rivers during the summer. Ideally, data should be collected twice, once in July and once in September. Unless further testing is done, evidence indicates no reason to sample or analyze females and males separately.

Seasonal differences.— Differences in slope confounded the analyses and indicated that stanzas of fish changed between time periods (Bagenal and Tesch 1978). Results of the 1989 data, when a change of condition was detected, were the opposite of what was expected. Condition may be expected to increase over the course of summer, but the data indicated a slight decrease in 1989. Results showing "no change" in condition could be explained in that feeding Dolly Varden char may enter the coastal environment prior to sampling efforts. Body condition could have rebounded from winter minimums prior to our July sampling. Further utilization of food may be directed toward growth and reproduction rather than condition. Alternatively, condition of Dolly Varden char may not change within the summer season.

Samples should be taken during the same time period each year. Greater effort to sample all size intervals equally may improve the unequal slope estimates if all size groups are present. Another strategy might be an analysis of a limited size range of the data, possibly of only one life stage (e.g., adults from 350 to 500 mm). Slope estimates for fish from a limited size range would be expected to be equal (Bagenal and Tesch 1978).

Overwintering.— Reduction of condition would be expected during the winter as stored nutrients are consumed by the body. Such changes were not detected in two winters; however, the opposite effect was observed during the winter of 1989-90. Several explanations are possible. The simplest explanation is to interpret the non-significant result as an indication that condition did not change during the winter. Alternatively, as with seasonal differences, sampling may not have been early enough in the open water season to measure the time of lowest condition. By July, feeding may have already begun and fish condition may have rebounded from winter minimums. Also, evidence indicates that some fish replace energy rich oils with water (W. B. Griffiths, LGL Alaska, personal communication), thus fat stores would decrease while weight remained unchanged or possibly increased. One could conclude, following the above reasoning, that weight-length data may not be an adequate measure of the condition or health of a fish population overwintering and potentially a chemical analysis such as proximate analysis (Anderson and Gutreuter 1983) might be necessary to detect changes. Given current results, further study of the effects of winter on fish condition appear unnecessary unless sampling times (earlier spring sampling) or a new method (proximate analysis) could be implemented.

Spatial differences.— Among-area differences were not expected since tagging data indicated that migration and dispersal from overwintering rivers to summer feeding areas cause extensive mixing of stocks across the Beaufort Sea coast. Differences may have been caused by site-specific environmental conditions such as water temperature or food availability.

The condition differences necessitate site-specific sampling if human-caused perturbations are to be monitored adequately. Pairwise F-tests of fish collected in July (Table 2.16) grouped areas differently for all data combined compared to grouping of only the 1991 data. One possible explanation is that changes in the environment during 1991 were responsible for the changes in statistical grouping. The paucity of data, however, prevents any conclusions and leaves new hypotheses untested.

Annual differences.— Annual variation of environmental conditions in Arctic regions are well documented. High variation of condition among years might be expected. Weight-length relationships from 1988 and 1991 had low intercept values which equate to low fish condition relative to 1989 and 1990.

The ice pack did not recede appreciably from the mainland during 1988 and 1991. Low fish condition could be related to pack ice through direct or indirect factors. First, lower water temperature might affect metabolism and activity level. Water temperature data were not collected until August 13 in 1988; however, water temperatures in Jago Lagoon ranged from 2-6°C (Hale 1990) on that date compared to 6-8°C on August 16, 1989 (Hale 1991). In Kaktovik Lagoon differences were slightly larger for those dates, 6-7°C compared to 9->11°C, respectively (Hale 1990, 1991). Temperatures summarized in box plots support Hale's findings and further highlight annual differences (Figures 2.47, 2.50, 2.51, 2.58). A second factor might be reduced food abundance. Reduced wind-driven upwelling would lower food transport from marine to nearshore-brackish areas (Craig 1984, Gallaway et al. 1991). Third, shading from pack ice could lower condition indirectly by reducing primary production in offshore areas. Finally, severity of the ice pack could be related to the timing of river break up. Delayed river break up in years of severe ice would reduce the time available to feed in productive nearshore waters.

Additional data on primary production, the severity of the ice pack, and the timing of river break up (entry of char into the coastal environment) would help identify possible mechanisms causing annual variation. Discovery of the mechanisms would allow similar years to be used in analyses and account for annual variation. This would shorten the study time and provide a more definitive answer to questions concerning the impact of development on condition.

Age and Growth

Growth of fish has important implications for understanding the dynamics of populations (Johnson 1980). Patterns of length and growth rates through time reflect biological events such as availability of food, habitat, and physiological stress (Rice 1990).

Age and length distributions of Dolly Varden char from Arctic Refuge waters correlate well with other studies along the Beaufort Sea coast (Craig and McCart 1976; Craig 1977; Griffiths et al. 1977; Johnson 1980). Primary modes in bimodal length distributions such as ours may represent increase of growth as a majority of the young fish enter marine waters for the first time (Johnson 1980). Secondary modes may be indicative of sexual maturity or the length at which Dolly Varden char can begin to exploit a different (i.e., larger) or more abundant prey. Johnson (1980) states that multi-modal length distributions indicate different habitats in time and space. As shown by the length frequency plots (Figures 2.44-2.46), these distributions change in time and space, indicating growth of a cohort or movement of the different cohorts in and out of sampling areas.

In some Dolly Varden char populations recruitment of young occurs over a long time span, hence, over several ages. Constant, long-term recruitment of fish into the sampled population produces a normally distributed age curve (Johnson 1980). Our length and age distributions showed these patterns even though the represent multiple stocks (Figure 2.44). Johnson (1980) states populations such as these are dependent more on size than on age. Implications of size-dependent populations include fairly constant lengths at first maturity over several year-classes. Future work on Dolly Varden char should include estimates of age and length at first maturity in a stock specific manner.

There was a distinct lack of very young and very old Dolly Varden char in our samples. The lack of age-0 Dolly Varden char in our samples is probably because this cohort had not yet left its natal streams during our sampling periods. The low frequency of older Dolly Varden char (Figures 2.44-2.58) in our distributions may be due to the fact that these mature Dolly Varden char were not vulnerable to our nets in time and/or space. For example, perhaps older char do not travel to brackish water or their stay is very short in years that they are to spawn.

Although sample sizes were small for length-at-age data, a few patterns could be detected. Overall mean length-at-age show fast growth until age 8 (Figure 2.44). Upon reaching sexual maturity at this age, Dolly Varden char use energy more for gonadal production then for somatic growth (Craig 1984). Wide overlap in mean lengths were also evident (Table 2.15). Overlap between ages have been reported for other Arctic areas (Craig and Mann 1974; Griffiths et al. 1975; 1977; Johnson 1976, 1980; Craig 1977; Lawrence et al. 1984; Wiswar and West 1987; Bond and Erickson 1987; Whitmus et al. 1987; Palmer and Dugan 1990) and are characteristic of unexploited Arctic populations (Johnson 1972).

We detected differences among areas and years for some of the comparisons (Tables 2.21, 2.22). Growth differences among areas should probably not be considered biologically significant because Dolly Varden char are known to be migratory within a season, travelling between sampling areas (This study). The statistical differences may be a result of small sample sizes. Determination of geographic differences in lengths would necessitate identification and tracking of individuals with sonic tags.

Among-year differences in length would be expected assuming Dolly Varden char reflected growth gained the previous summer. Environmental condition could cause differential growth. One such condition would be water temperature. From our results, yearly mean lengths were consistently larger in 1991 and smaller in 1989. From our physical data, 1988 water temperatures were the coldest of all years (This study), reflected in smaller lengths during 1989. The larger lengths in 1991 could be a result of warm temperatures that occurred in 1989 and 1990 (Figure 2.47, 2.50, 2.51, and 2.58).

The current study did not target age and growth as a priority in the study design. Effective future study of age and growth of Dolly Varden char would require a long-term, validated, continuous project with substantially more collection effort (both within and between years) than in this project. Long-term data collection would be necessary to discern whether our findings are substantive or merely the effects of small sample sizes. Validation studies of ageing techniques also would be necessary where age data are the basis for management decisions (Mayo et al. 1981). For viable statistical examination, sample sizes must remain adequately large after stratifications of time, space, and gender. Methods to determine age indirectly from length frequencies (genders pooled) are possible with careful study design. More sampling should be done in freshwater drainages, deltas, and coastal areas to understand the dynamics of the age-0 Dolly Varden char.

Other important factors affecting the ecology of Dolly Varden char are those that limit growth of both individuals and populations. These factors include stresses related to food availability and overwintering habitat, plus the role that variable water temperature and salinity regimes play in the bioenergetics of Dolly Varden char during the open-water season.

Movements

Movement results agree with previously published results (Osborne et al. in preparation; LGL Alaska, 1990). Dolly Varden char move into coastal rivers to overwinter and leave rivers to feed in coastal waters during the summer. Summer dispersal is widespread and crosses refuge boundaries into Alaskan and Canadian waters. Dispersal does not seem to be related to a fixed location since fish caught in one area were found in other areas in following years. Varying dispersal along with data indicating movement of fish from one sampling area to another within a sampling year suggest stock mixing across the coast. Genetic studies (Everett et al. in preparation a; Everett et al. in preparation b) also suggest a mixing of stocks in Arctic Refuge waters. While mixing of stocks was prevalent, it was also apparent that within a year Dolly Varden char did remain in one sampling area for many days at a time. This would indicate that feeding within a single lagoon is at times more advantageous than travelling to a new lagoon through marine water.

Implications of mark and tag data are numerous. Future sampling design should consider fish movement. For example, mixed stocks would not require site specific sampling for age data, but since within one year fish might stay in one area with unique environmental conditions, differences in fish condition might or might not exist between areas. Sport and subsistence harvest levels in one area, a river or coastal lagoon, could affect abundance within the refuge, on state lands, or internationally. Also, increasing harvest levels could cause declines of low production spawning stocks that would be undetectable in coastal waters. This implies abundance in Dolly Varden char must be monitored on the spawning grounds where stocks are separate.

Environmental Influences on CPUE

We detected few consistent patterns of association between CPUE and environmental variables with the sampling design employed by this study. The strongest association in Beaufort Lagoon occurred in 1991, when temperature and CPUE were directly related. An inspection of the time series of these data shows a general decrease in Dolly Varden char CPUE from late July to early September, coincident with a gradual decrease in lagoon temperatures. This observed relationship, on a seasonal scale, does not necessarily imply a dependency of catch on temperature; the two may have covaried for independent reasons. While Craig and Haldorson (1981) found a similar overall shortage of significant correlations between catch and physical factors in Simpson Lagoon, they report a significant correlation between Dolly Varden char catch and both temperature and salinity for the summer of 1978.

It is interesting to note that Dolly Varden char catches in Kaktovik Lagoon were always higher (1988, 1991) or as high (1989-90) as catches in Jago Lagoon. Synoptic thermohaline patterns for these lagoons during 1988 and 1989 indicate that Kaktovik Lagoon, a pulsing lagoon system, is generally less affected by offshore marine processes than is the limited exchange Jago Lagoon system (Hale 1990, 1991). Absolute correlations between catch and temperature/salinity were generally higher in Kaktovik Lagoon, indicating perhaps a more definitive distributional response to a more stable environment. Future studies of effects of physical variables on migratory fish distribution might be enhanced by detailed examination of proximate lagoons such as these. Sampling proximate systems may decrease the random variation in catch due to different coast-wide population distributions and thus aid the assessment of effects of the local physical environment on CPUE.

The inability to detect any consistent association between environmental variables and Dolly Varden char CPUE is not unexpected. Referring primarily to anadromous species, Craig (1989) noted that migration patterns of Arctic fishes can be quite complex. Arctic Refuge coastal waters may contain Dolly Varden char stocks from several different natal streams, including the Firth, Kongakut, Hulahula, Canning, and Sagavanirktok rivers (Craig and McCart 1976). Timing of seaward migration in spring from overwintering areas may vary by drainage and by fish size or age within a drainage. Timing of a return alongshore migration to overwintering areas may also vary, depending on the reproductive status of the fish (McCart 1980). These differential coastal movement patterns suggest that, for a given area and time, Dolly Varden char abundances can be expected to vary greatly due to large-scale migration trends alone. When environmental influences are overlain on variable migration patterns, even gross dependencies can be difficult to detect. For migratory species, catch rates in coastal lagoons reflect not only environmental influences which may confine fish to nearshore corridors, but also, possibly to a larger extent, the total number of fish which are passing through the region at that point in time. With no knowledge of this latter component, any assessment of the former effect is tenuous at best.

While there is little doubt that anadromous species prefer the warmer, less saline coastal waters over the offshore marine environment (Craig et al. 1985; Dempson and Kristofferson 1987; Houghton and Whitmus 1988; Craig 1989), the factors governing daily microhabitat selection remained unclear. The hydrography of shallow waters of the Beaufort Sea coast is primarily wind-driven, with shifts in wind direction reflected by current shifts within 2-4 h (Hale 1990, 1991). The constant search for thermal and/or salinity optima in this dynamic environment may result in apparent random movements by the local fish populations (Neill and Gallaway 1989). Coastal geology and meteorological events may also combine to isolate coastal water masses and direct them offshore (LGL 1991). The effects of these events may confound nearshore and lagoon-oriented thermohaline and fish CPUE monitoring efforts. Underwater topography may also affect the nearshore distribution of migrating fishes (Craig and Haldorson 1981) and thus represents another variable which should be controlled for in future experimental designs.

Local prey abundance may also interact with physical factors in determining patterns of nearshore Dolly Varden char distribution. Feeding is a primary activity of fishes inhabiting the coastal waters during summer (Craig and Haldorson 1981) and char abundance has been associated with invertebrate abundances along the western Beaufort coast (Cannon et al. 1987). Even short-term variations in prey abundances may similarly affect daily and seasonal distribution patterns of char in Arctic Refuge coastal waters.

Our results indicate the need for directed and intensive site-specific monitoring efforts in order to assess any possible effects of coastal development on use of coastal waters by migratory fishes. Complex interactions between meteorologic, hydrographic, and biological variables undoubtedly influence coastal migration patterns. Should development appear imminent, possible impacts could be assessed more effectively with data from a more spatially focused and synoptic sampling program.

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